

Fig. 1a

Fig. 1b

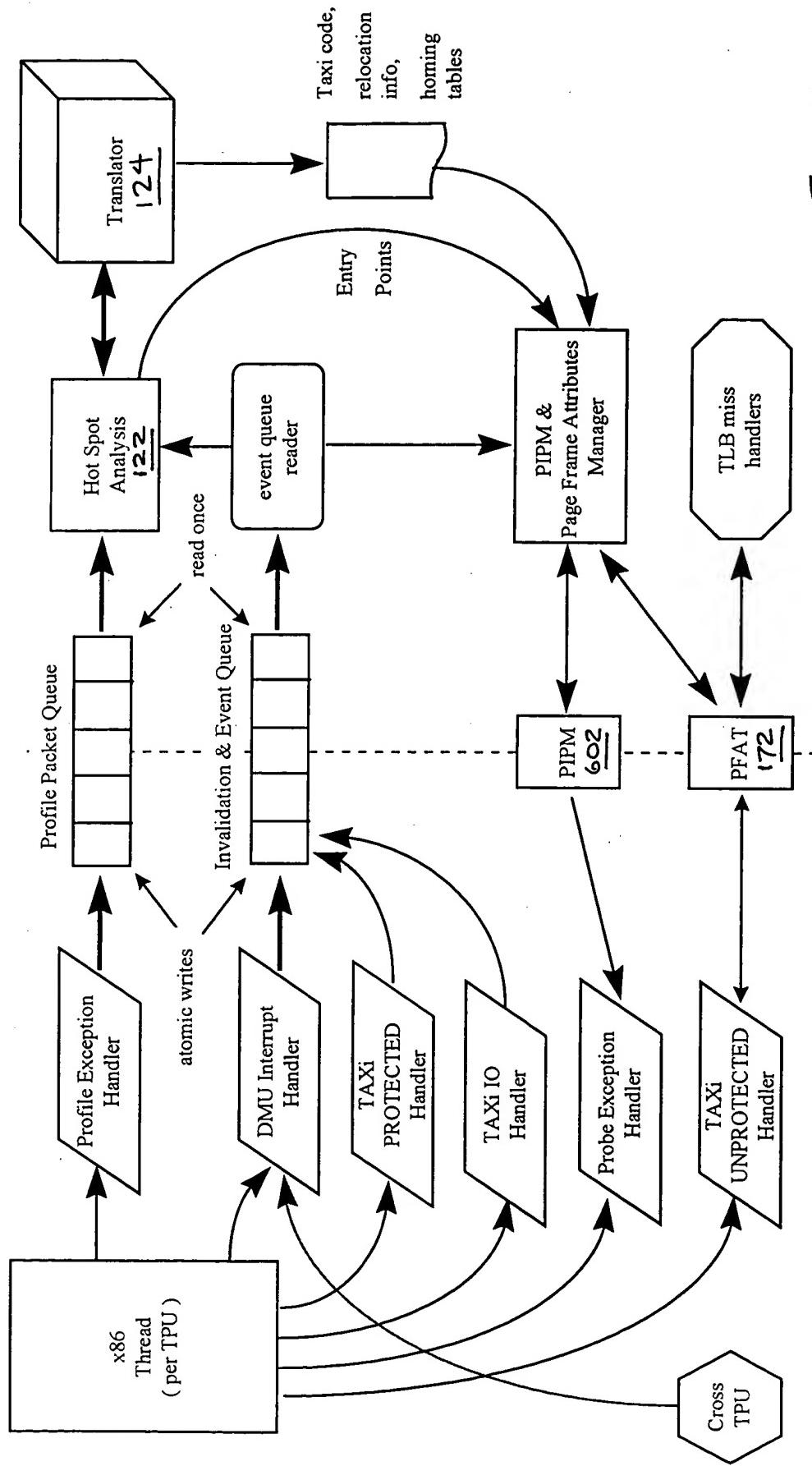
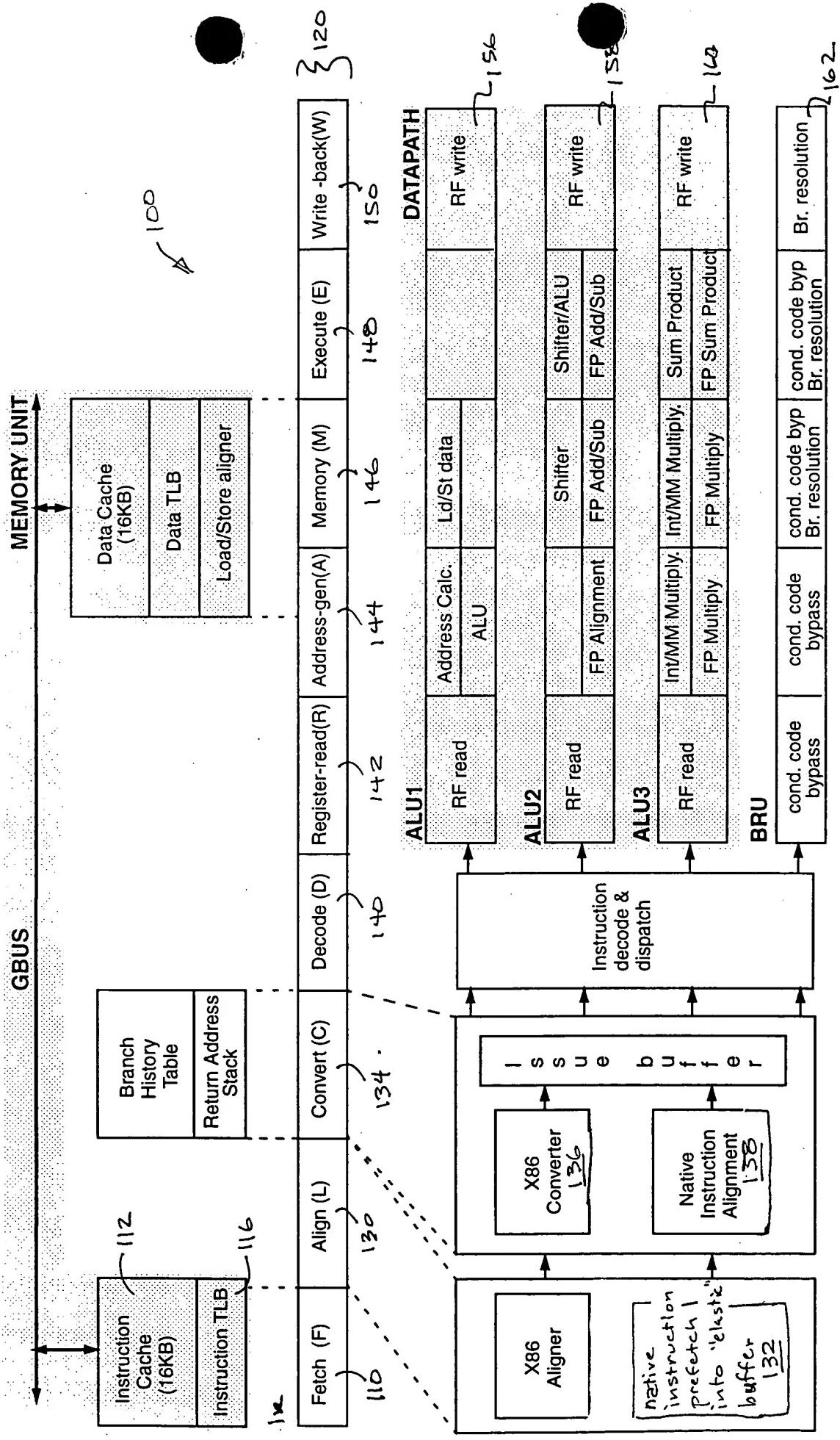
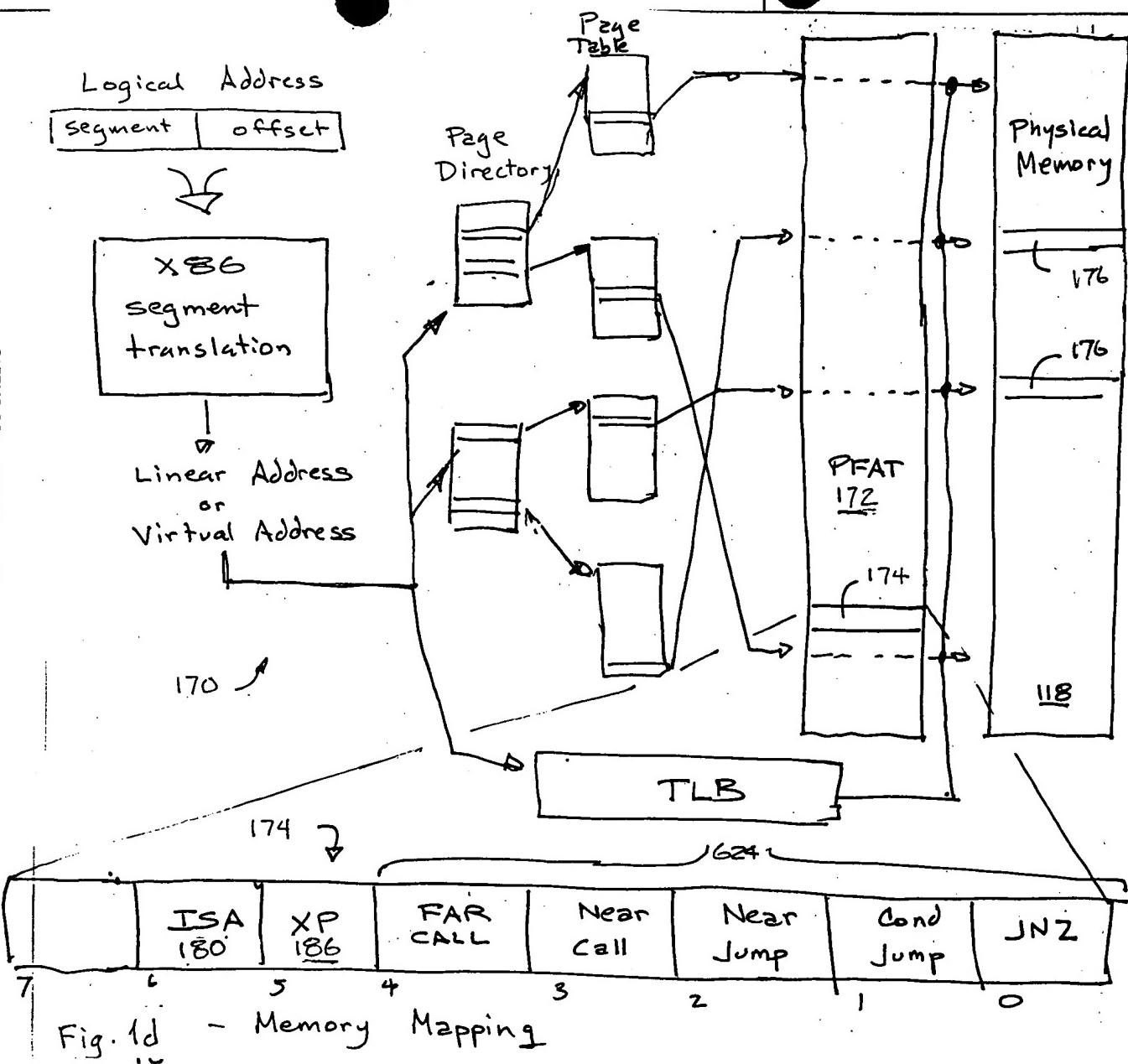


Fig. 1c





22-141 50 SHEETS
22-142 100 SHEETS
22-144 200 SHEETS



22.141 50 SHEETS
 22.142 100 SHEETS
 22.144 200 SHEETS

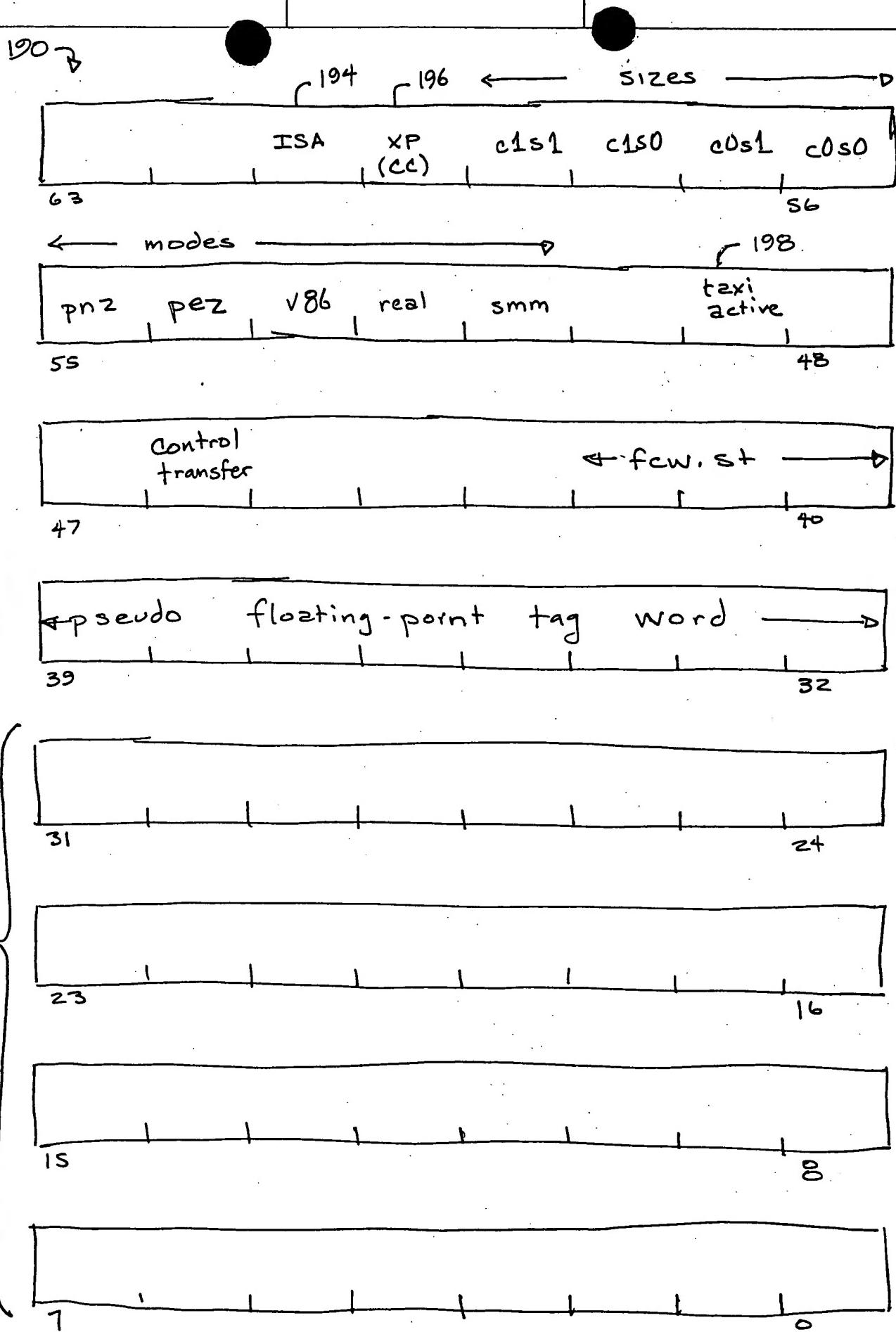


Fig. 1e

22-141 50 SHEETS
22-142 100 SHEETS
22-144 200 SHEETS

I-TLB property bits	Decoded property values			Interpretation	Instructions sent to:	Collect profile trace-packets?	Probe for translated code	I/O memory reference exceptions
	ISA	CC	200					
00	Tap	Tap	no	Native code observing native RISCy calling conventions	Native decoder	No	No	Fault if SEG.tio
01	Tap	x86	no	Native code observing x86 calling conventions	Native decoder	No	No	Fault if SEG.tio
10	x86	x86	no	x86 code, unprotected - TAX! profile collection only	x86HW converter	If enabled	No	Trap if profiling
11	x86	x86	yes	x86 code, protected - TAX! code may be available	x86HW converter	If enabled	Based on I-TLB probe attributes	Trap if profiling

Fig. 2a Significance of the I-TLB property bits

180, 182
184, 186
186
204

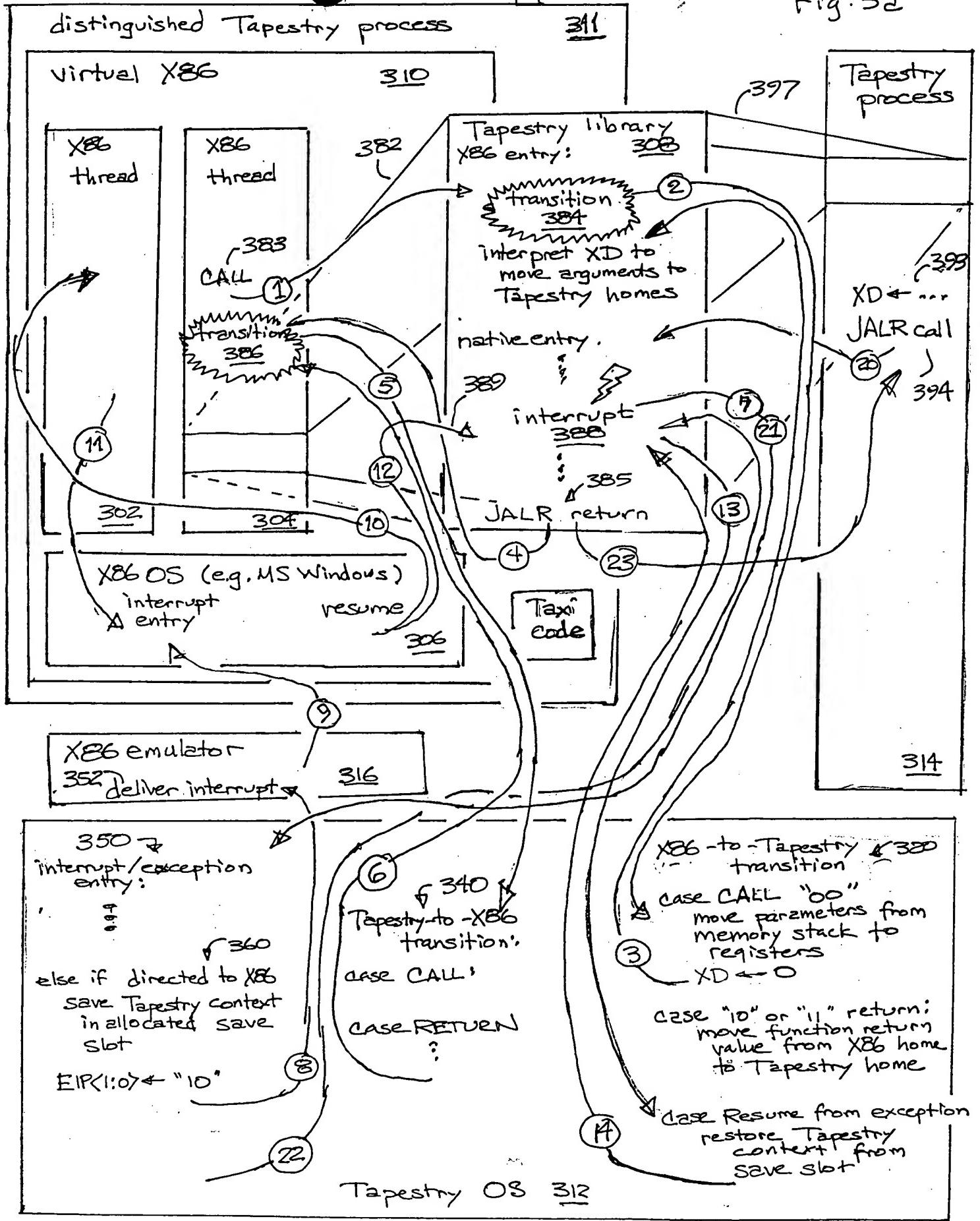
Transition (source => dest) ISA & CC property values		Handler Action
00	=> 00	No transition exception
00	=> 01	VECT_xxx_X86_CC exception - handler converts from native to x86 conventions
00	=> 1x	VECT_xxx_X86_CC exception - handler converts from native to x86 conventions, sets up expected emulator and profiling state
01	=> 00	VECT_xxx_TAP_CC exception - handler converts from x86 to native conventions
01	=> 01	No transition exception
01	=> 1x	VECT_X86_ISA exception [conditional based on PCW.X86_ISA_ENABLE flag] - sets up expected emulator and profiling state
1x	=> 00	VECT_xxx_TAP_CC exception - handler converts from x86 to native conventions
1x	=> 01	VECT_TAP_ISA exception [conditional based PCW.TAP_ISA_ENABLE flag] - no convention conversion necessary
1x	=> 10	No transition exception - [profile complete possible, probe possible]
1x	=> 11	No transition exception - [profile complete possible, probe NOT possible]

Fig. 2b ISA & CC transition exception flow

	name	description	type
242	VECT_call_X86_CC	push args, return address, set up x86 state	fault on target instruction
244	VECT_jump_X86_CC	set up x86 state	fault on target instruction
246	VECT_ret_no_fp_X86_CC	return value to eax:edx, set up x86 state	fault on target instruction
248	VECT_ret_fp_X86_CC	return value to x86 fp stack, set up x86 state	fault on target instruction
250	VECT_call_TAP_CC	x86 stack args, return address to registers	fault on target instruction
252	VECT_jump_TAP_CC	x86 stack args to registers	fault on target instruction
254	VECT_ret_no_fp_TAP_CC	return value to RV0	fault on target instruction
256	VECT_ret_any_TAP_CC	return type unknown, setup RV0 and RVDP	fault on target instruction

Fig. 2c CC transition exceptions

Fig. 32



Flat 32-bit "Near" Address Space

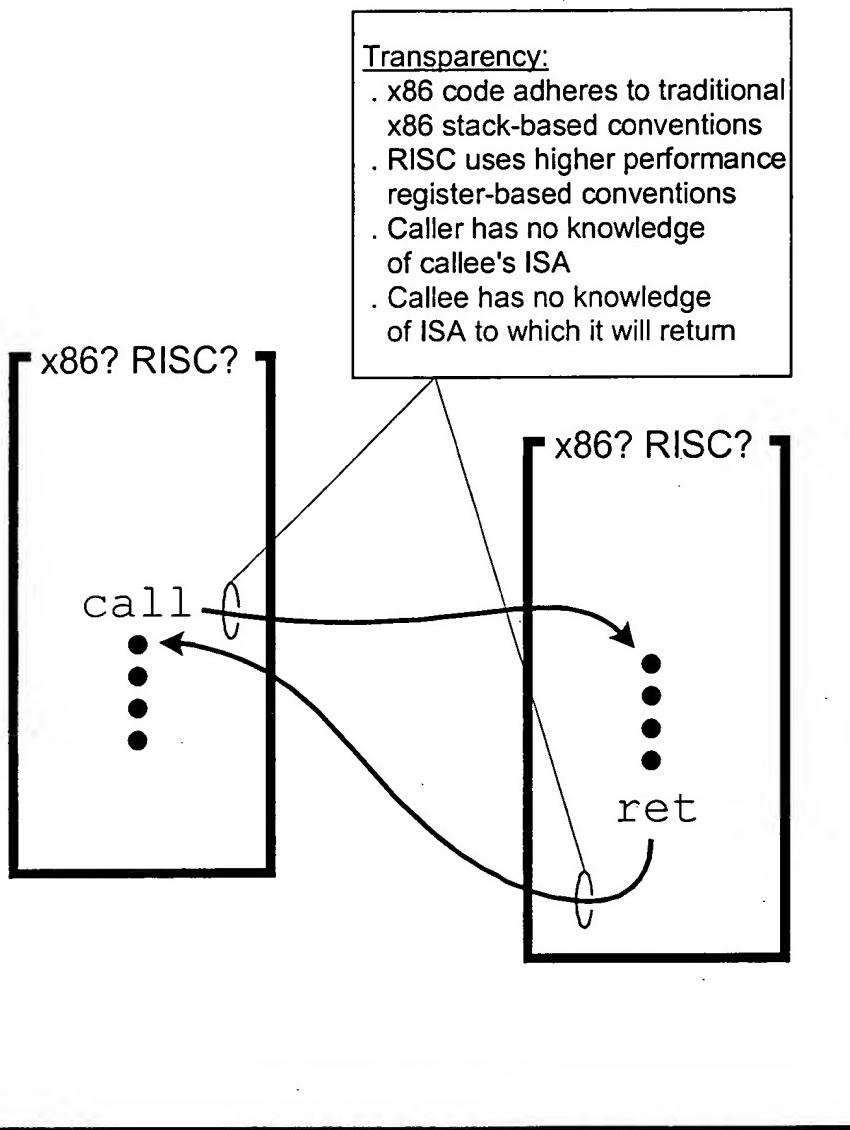
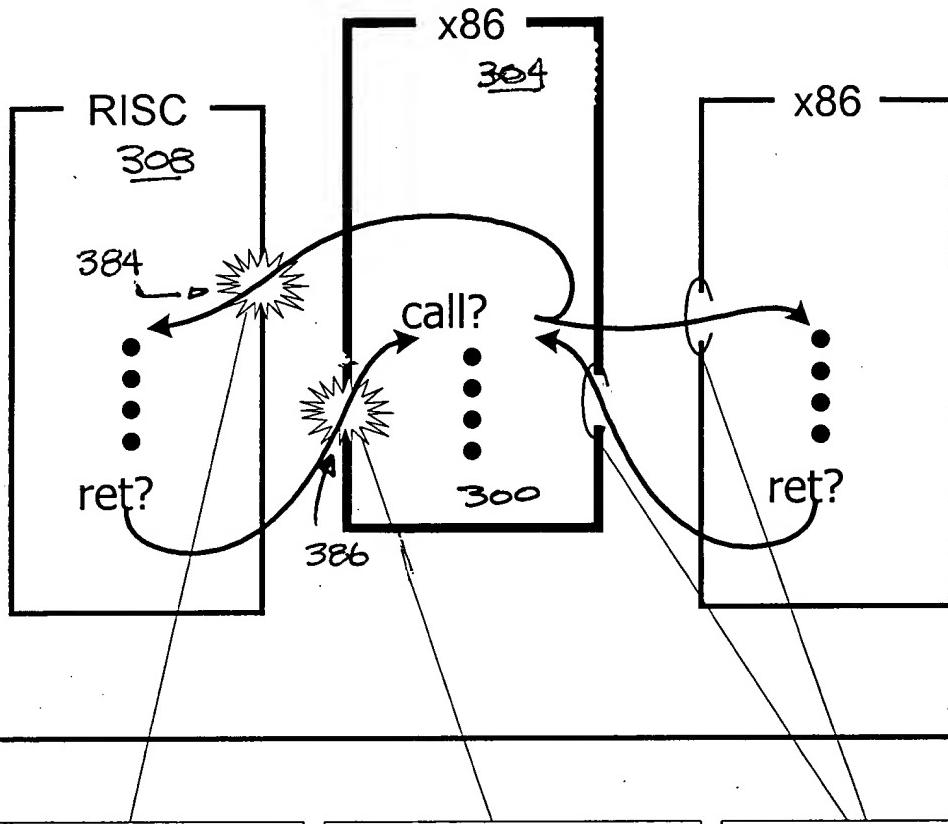


Fig. 3b

Flat 32-bit "Near" Address Space



x86 → RISC transition:
map x86 call to RISC
322 (Fig. 3h)

RISC → x86 transition:
map x86 return to RISC
342 (Fig. 3i)

no ISA transition:
no mapping required

Fig. 3c

Flat 32-bit "Near" Address Space

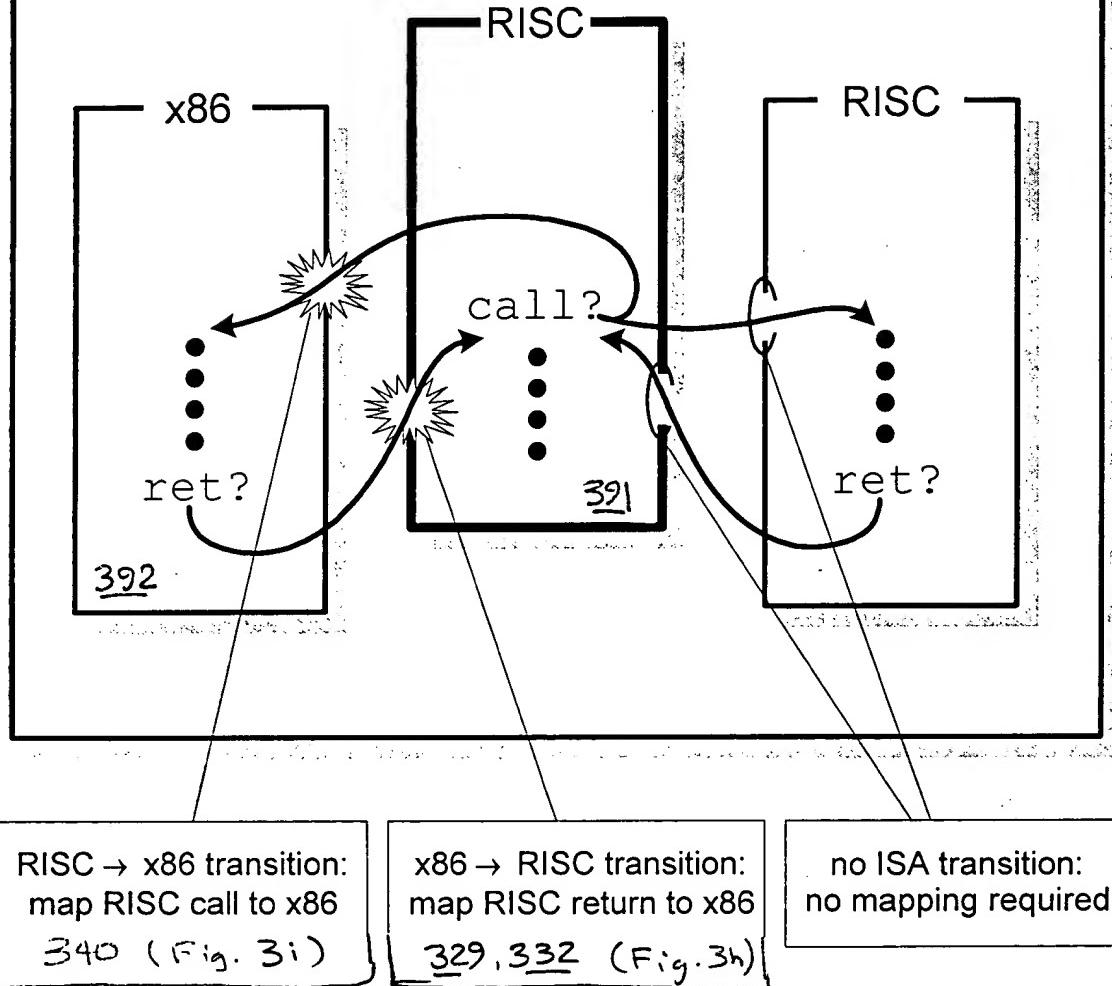


Fig. 3d

Flat 32-bit "Near" Address Space

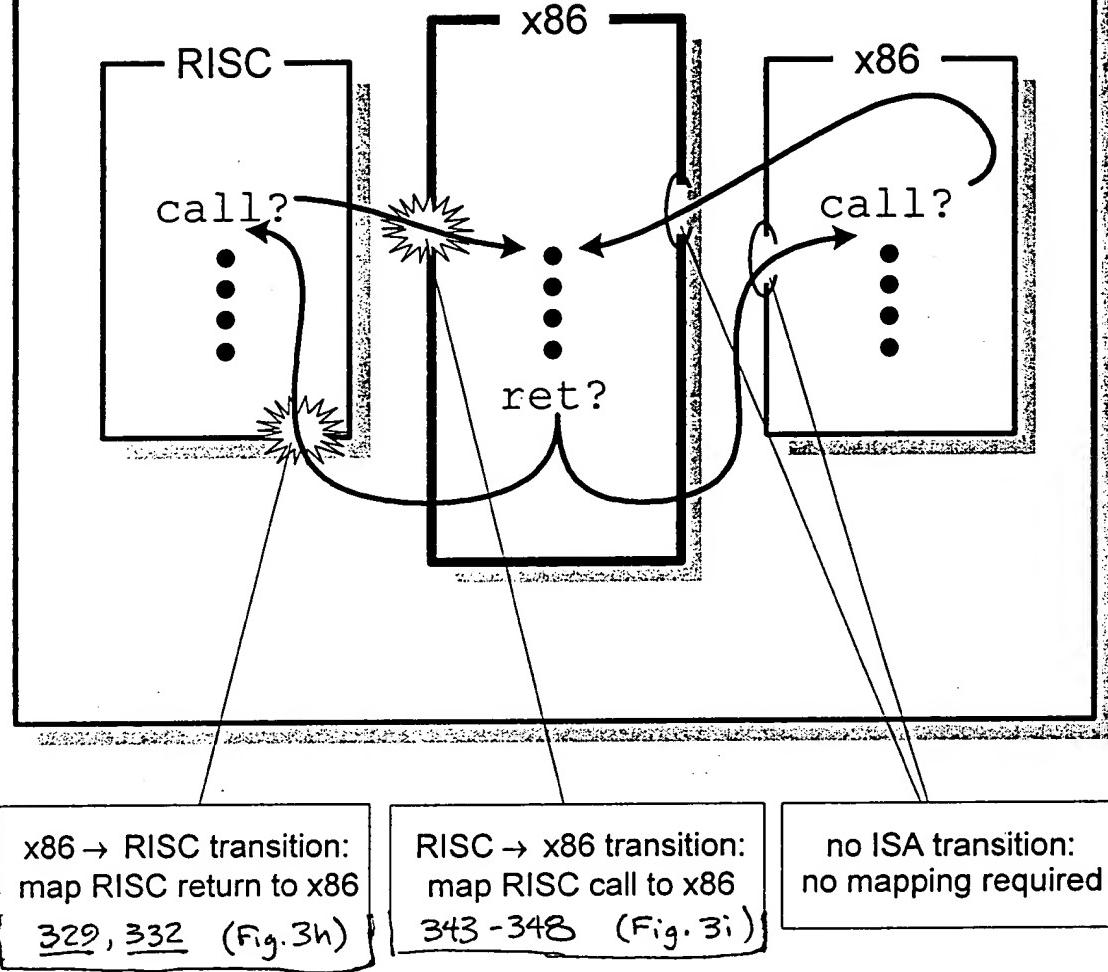


Fig. 3e

Flat 32-bit "Near" Address Space

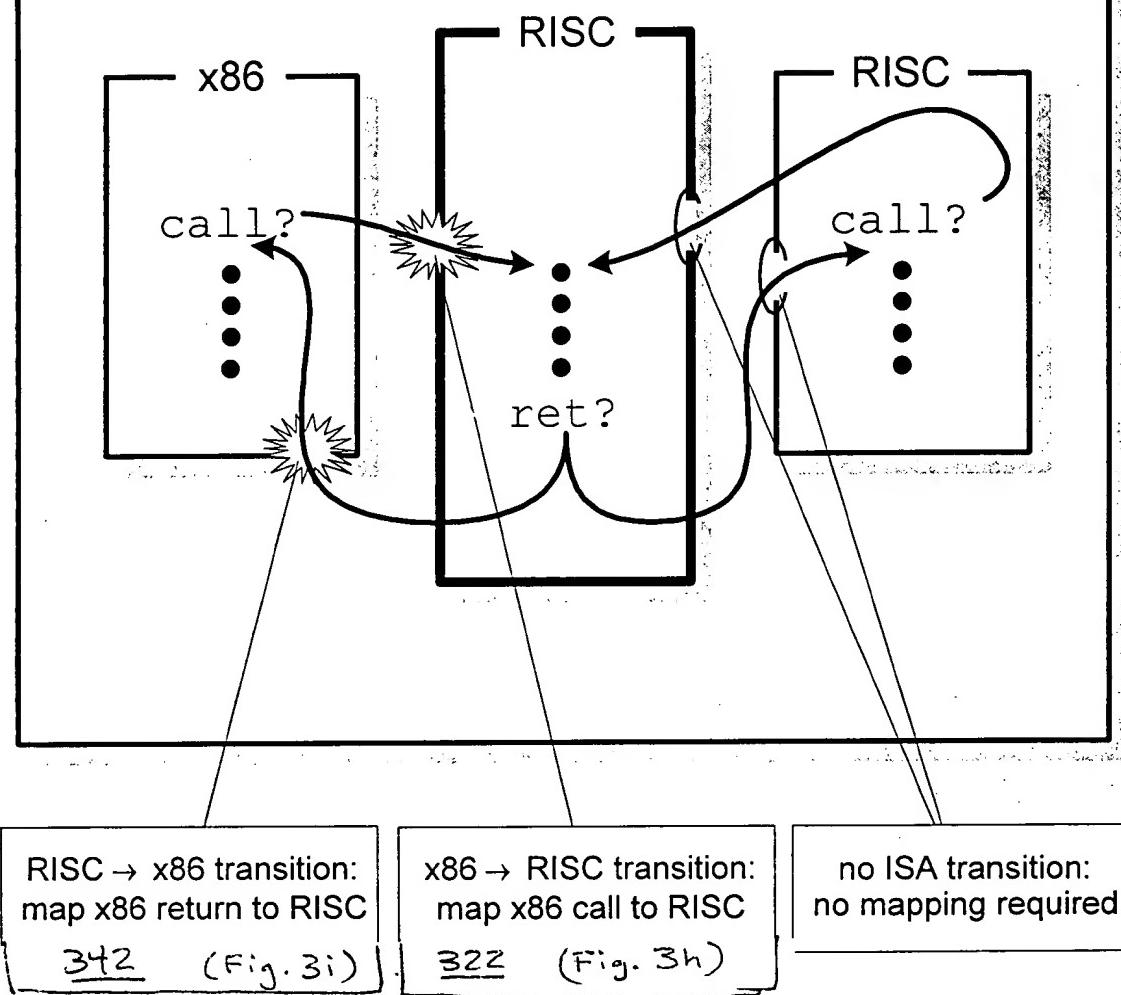


Fig. 3f

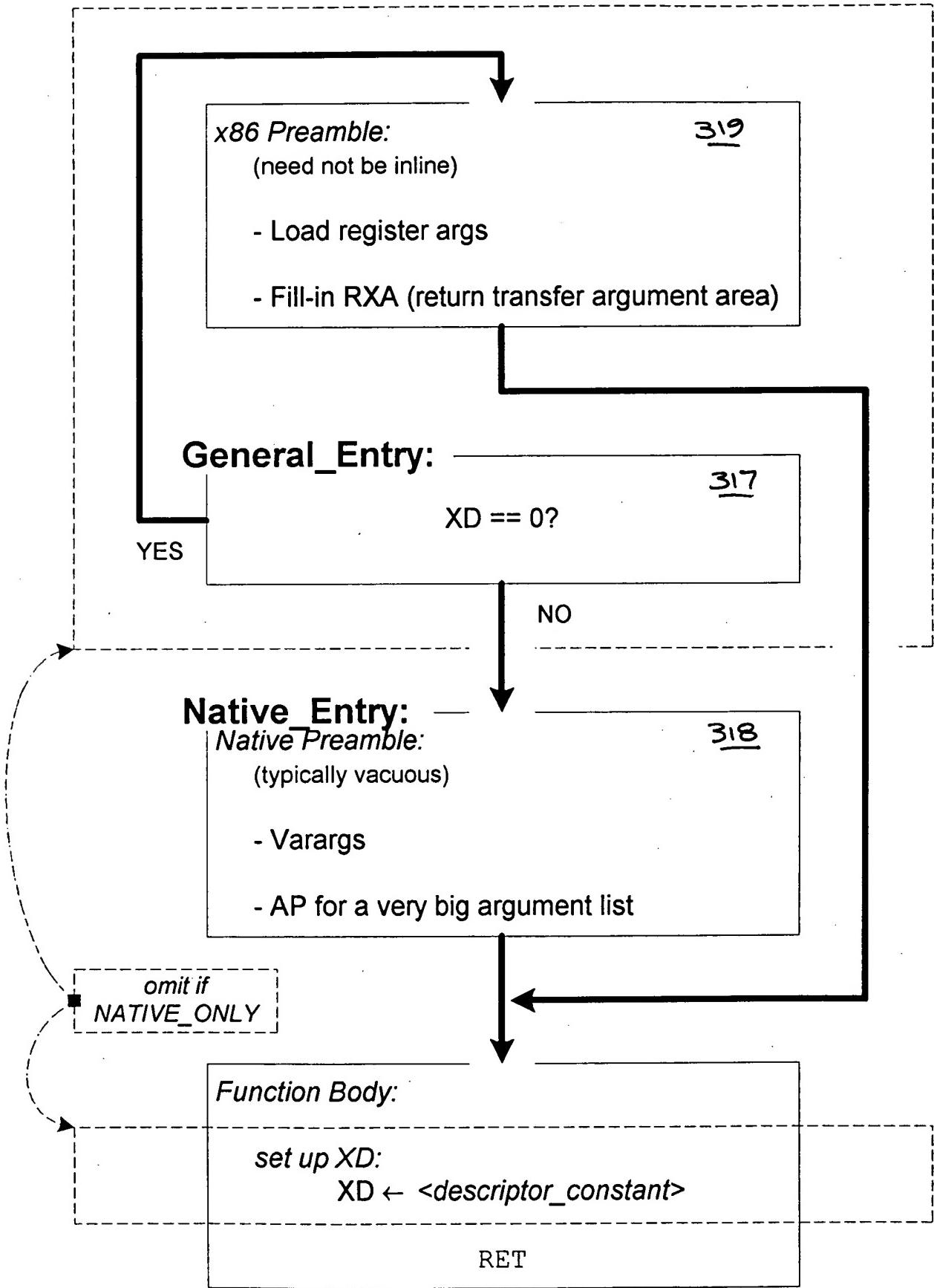


Fig. 3g

X86-to-Tapestry transition exception handler

320

// This handler is entered under the following conditions:
// 1. An x86 caller invokes a native function
// 2. An x86 function returns to a native caller
// 3. x86 software returns to or resumes an interrupted native function following
// an external asynchronous interrupt, a processor exception, or a context switch

321

dispatch on the two least-significant bits of the destination address {
case "00" // calling a native subprogram

// copy linkage and stack frame information and call parameters from the memory
// stack to the analogous Tapestry registers

LR ← [SP++] // set up linkage register ~ 323

AP ← SP // address of first argument ~ 324

SP ← SP - 8 // allocate return transfer argument area ~ 326

SP ← SP & (-32) // round the stack pointer down to a 0 mode 32 boundary ~ 327

XD ← 0 // inform callee that caller uses X86 calling conventions ~ 328

322

case "01" // resuming an X86 thread suspended during execution of a native routine

if the redundant copies of the save slot number in EAX and EDX do not match or if
the redundant copies of the timestamp in EBX:ECX and ESI:EDI do not match {

3371

// some form of bug or thread corruption has been detected

goto TAPESTRY_CRASH_SYSTEM(thread-corruption-error-code) ~ 372

}

save the EBX:ECX timestamp in a 64-bit exception handler temporary register

(this will not be overwritten during restoration of the full native context)

3373

use save slot number in EAX to locate actual save slot storage ~ 374

restore full entire native context (includes new values for all x86 registers) ~ 375

if save slot's timestamp does not match the saved timestamp { ~ 376

// save slot as been reallocated; save slot exhaustion has been detected

goto TAPESTRY_CRASH_SYSTEM(save-slot-overwritten-error-code) ~ 377

370

}

free the save slot ~ 378

case "10" // returning from X86 callee to native caller, result already in registers

RV0<63:32> ← edx<31:00> // in case result is 64 bits ~ 333

332

convert the FP top-of-stack value from 80 bit X86 form to 64-bit form in RVDP ~ 334

SP ← ESI // restore SP from time of call ~ 337

case "11" // returning from X86 callee to native caller, load large result from memory

RV0..RV3 ← load 32 bytes from [ESI-32] // (guaranteed naturally aligned) ~ 330

329

SP ← ESI // restore SP from time of call ~ 337

}

EPC ← EPC & -4 // reset the two low-order bits to zero ~ 336

RFE ~ 338

Fig. 3h

Tapestry-to-X86 transition exception handler

// This handler is entered under the following conditions:
 // 1. a native caller invokes an x86 function
 // 2. a native function returns to an x86 caller
 switch on XD<3:0> { ~ 341

340

XD_RET_FP: // result type is floating point
 F0/F1 ← FINFLATE.de(RVDP) // X86 FP results are 80 bits
 SP ← from RXA save // discard RXA, pad, args
 FPCW ← image after FINIT & push // FP stack has 1 entry
 goto EXIT

XD_RET_WRITEBACK: // store result to @RVA, leave RVA in eax
 RVA ← from RXA save // address of result area
 copy decode(XD<8:4>) bytes from RV0..RV3 to [RVA]
 eax ← RVA // X86 expects RVA in eax
 SP ← from RXA save // discard RXA, pad, args
 FPCW ← image after FINIT // FP stack is empty
 goto EXIT

342

XD_RET_SCALAR: // result in eax:eda
 edx<31:00> ← eax<63:32> // in case result is 64 bits
 SP ← from RXA save // discard RXA, pad, args
 FPCW ← image after FINIT // FP stack is empty
 goto EXIT

XD_CALL_HIDDEN_TEMP: // allocate 32 byte aligned hidden temp
 esi ← SP // stack cut back on return ~ 343
 SP ← SP - 32 // allocate max size temp ~ 344
 RVA ← SP // RVA consumed later by RR
 LR<1:0> ← "11" // flag address for return & reload ~ 345
 goto CALL_COMMON

default: // remaining XD_CALL_xxx encodings
 esi ← SP // stack cut back on return ~ 343
 LR<1:0> ← "10" // flag address for return ~ 346

CALL_COMMON:
 interpret XD to push and/or reposition args ~ 347
 [-SP] ← LR // push LR as return address } 348
 EXIT:
 setup emulator context and profiling ring buffer pointer }
 RFE ~ 349 // to original target }

Fig. 3i

interrupt/exception handler of Tapestry operating system:

350

// Control vectors here when a synchronous exception or asynchronous interrupt is to be
// exported to / manifested in an x86 machine.

// The interrupt is directed to something within the virtual X86, and thus there is a possibility
// that the X86 operating system will context switch. So we need to distinguish two cases:
// either the running process has only X86 state that is relevant to save, or
// there is extended state that must be saved and associated with the current machine context
// (e.g., extended state in a Tapestry library call in behalf of a process managed by X86 OS)
if execution was interrupted in the converter – EPC.ISA == X86 {

// no dependence on extended/native state possible hence no need to save any
goto EM86_Deliver_Interrupt(interrupt-byte)

} else if EPC.Taxi_Active {

// A Taxi translated version of some X86 code was running. Taxi will rollback to an
// x86 instruction boundary. Then, if the rollback was induced by an asynchronous external
// interrupt Taxi will deliver the appropriate x86 interrupt. Else, the rollback was induced
// by a synchronous event so Taxi will resume execution in the converter, retriggering the
// exception but this time will EPC.ISA == X86

goto TAXi_Rollback(asynchronous-flag, interrupt-byte)

} else if EPC.EM86 {

// The emulator has been interrupted. In theory the emulator is coded to allow for such
// conditions and permits re-entry during long running routines (e.g. far call through a gate)
// to deliver external interrupts

goto EM86_Deliver_Interrupt(interrupt-byte)

} else {

// This is the most difficult case – the machine was executing native Tapestry code on
// behalf of an X86 thread. The X86 operating system may context switch. We must save
// all native state and be able to locate it again when the x86 thread is resumed.

361

allocate a free save slot; if unavailable free the save slot with oldest timestamp and try again
save the entire native state (both the X86 and the extended state)

save the X86 EIP in the save slot

overwrite the two low-order bits of EPC with "01" (will become X86 interrupt EIP) ~ 363

store the 64-bit timestamp in the save slot, in the X86 EBX:ECX register pair (and,

for further security, store a redundant copy in the X86 ESI:EDI register pair) 364

store the a number of the allocated save slot in the X86 EAX register (and, again for

further security, store a redundant copy in the X86 EDX register) 365

goto EM86_Deliver_Interrupt(interrupt-byte) ~ 369

353

354

360

362

363

364

365

350 ↗

Fig. 3j

```

typedef struct {
    save_slot_t *newer;           // pointer to next-most-recently-allocated save slot } 379c
    save_slot_t *older;          // pointer to next-older save slot
    unsigned int64 epc;          // saved exception PC/IP
    unsigned int64 pcw;          // saved exception PCW (program control word)
    unsigned int64 registers[63]; // save the 63 writeable general registers } 356
    ...
    timestamp_t timestamp;       // other words of Tapestry context ~ 358
    int timestamp;               // timestamp to detect buffer overrun ~ 358
    save_slot_ID;               // ID number of the save slot ~ 357
    boolean save_slot_is_full;   // full / empty flag ~ 359
} save_slot_t;

```

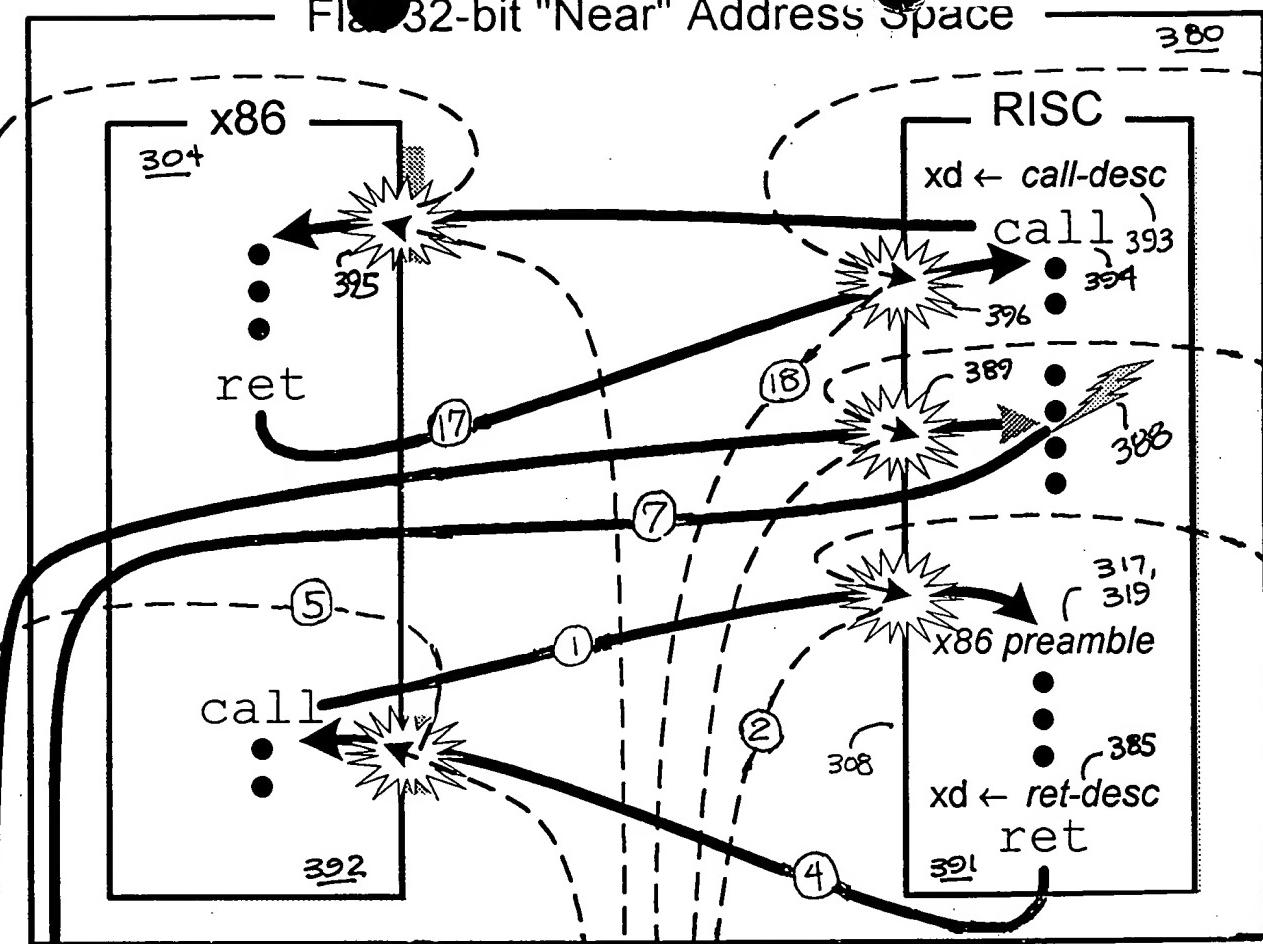
save_slot_t * save_slot_head; // pointer to the head of the queue ~ 379a
 save_slot_t * save_slot_tail; // pointer to the tail of the queue ~ 379b

System initialization

reserve several pages of unpaged memory for save slots

Fig. 3k

Fig. 3L



Prepare x86 exceps. or int.

- . Alloc free or oldest save slot
 - . Store timestamp & full state
 - . x86 regs \leftarrow save slot ID, TS
 - . EPC<1:0> \leftarrow 01

- Handler: x86 to RISC

- . LR \leftarrow [SP]
 - . SP \leftarrow SP + 4
 - . AP \leftarrow SP
 - . SP \leftarrow SP - 8 // ret area
 - . SP \leftarrow SP & (-32)
 - . XD \leftarrow 0

EPC<1:0> ≡ 01:

- . x86 regs points to save slot
 - . Using TS verify no overwrite
 - . Restore full state
 - . Free save slot
 - . EPC<1:0> ← 00

EPC<1:0> = 1x;

- . Reformat / reposition the function result per EPC<0>
 - . $SP \leftarrow ESI$
 - . $EPC<1:0> \leftarrow 00$

Handler: RISC to x86 —
XD contains return-descriptor:

- Interpret XD: 342
 - Reformat / reposition result
 - Load FPCW
 - SP \leftarrow [SP] // pop RA & args

XD contains call-descriptor:

- . ESI \leftarrow SP
 - . Interpret XD, reposition args
 - . LR<1:0> \leftarrow 1x per XD
 - . Push LR as RA (ret addr)

Fig. 3L

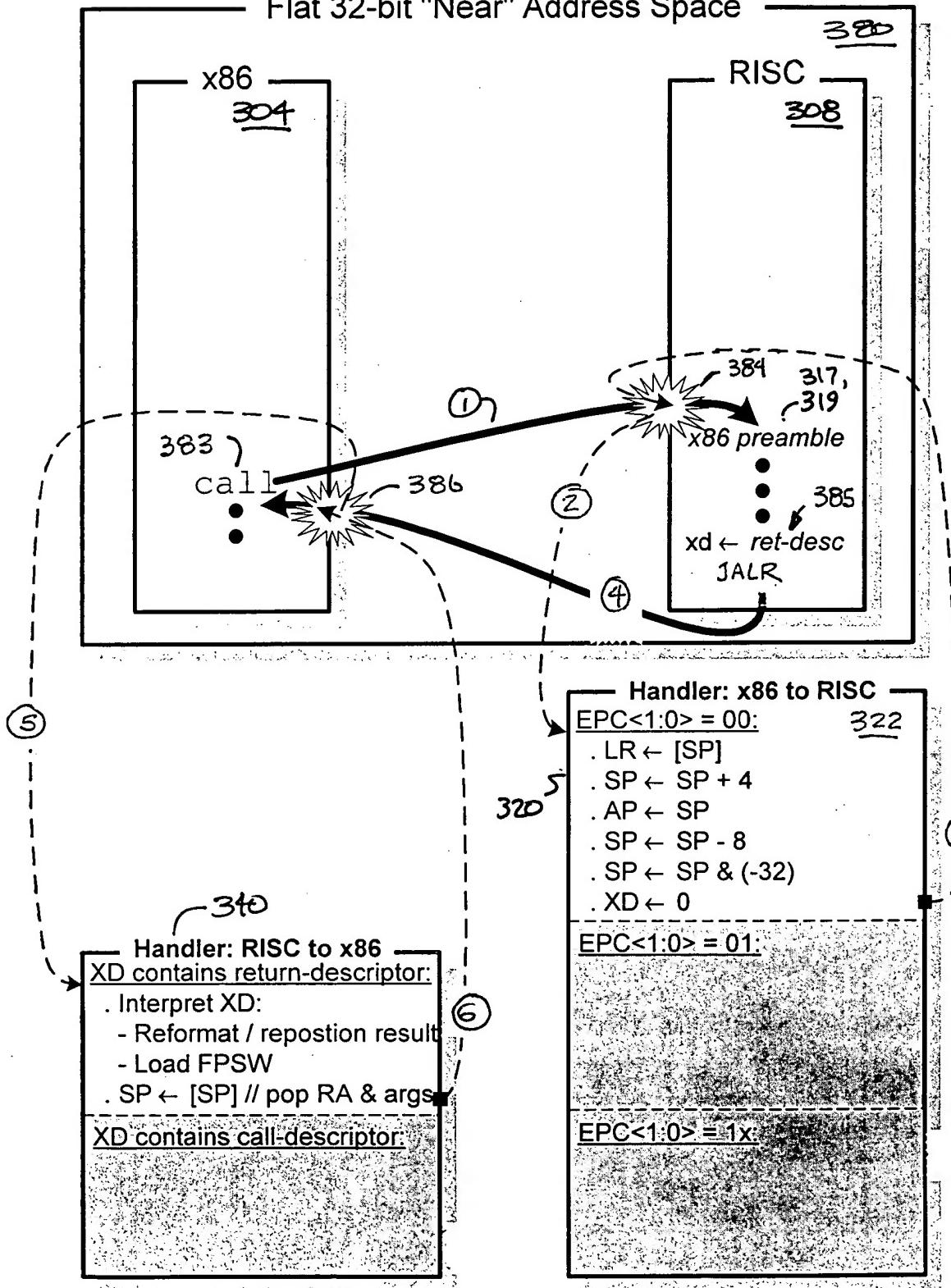


Fig. 3m

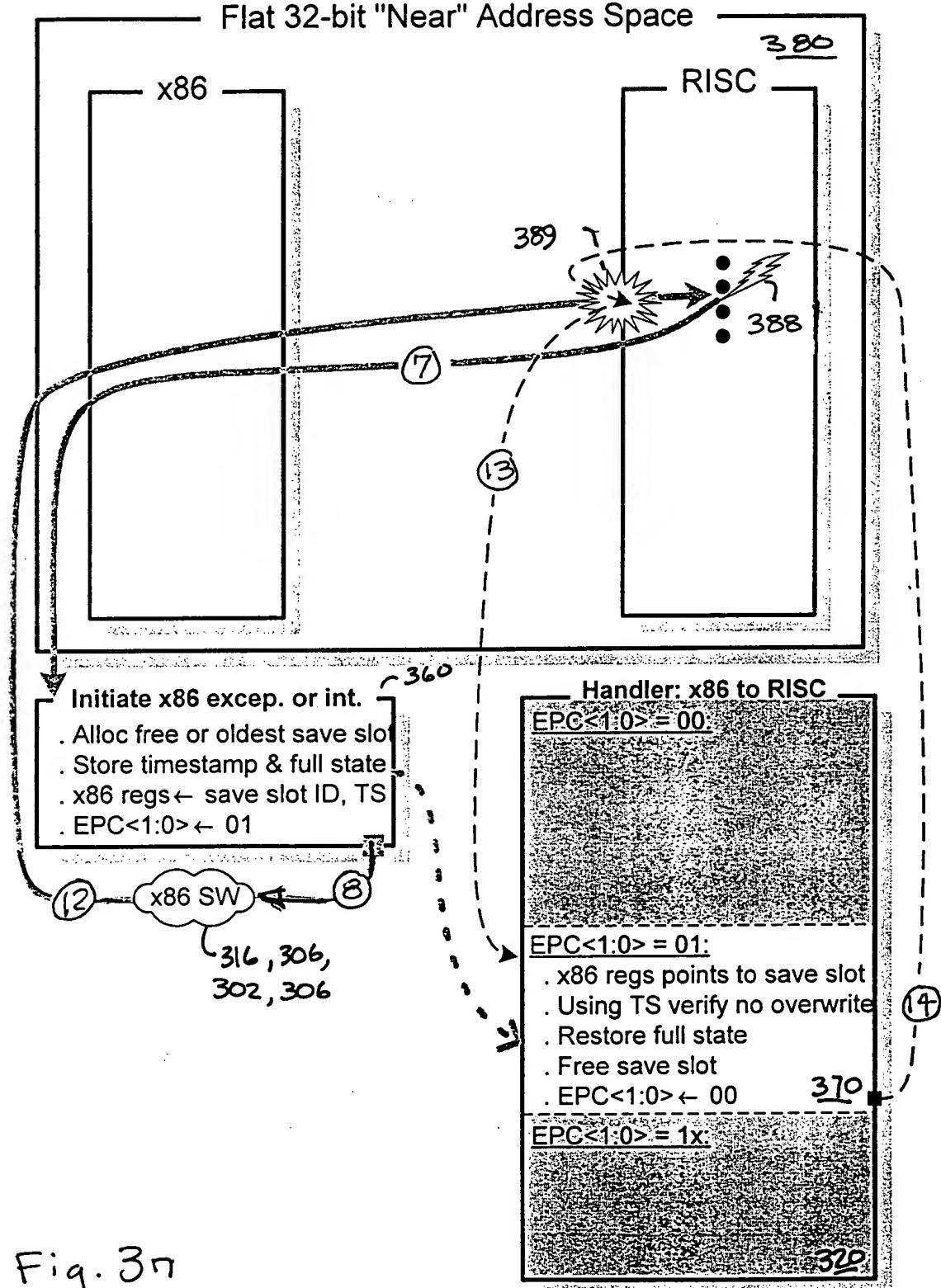


Fig. 37

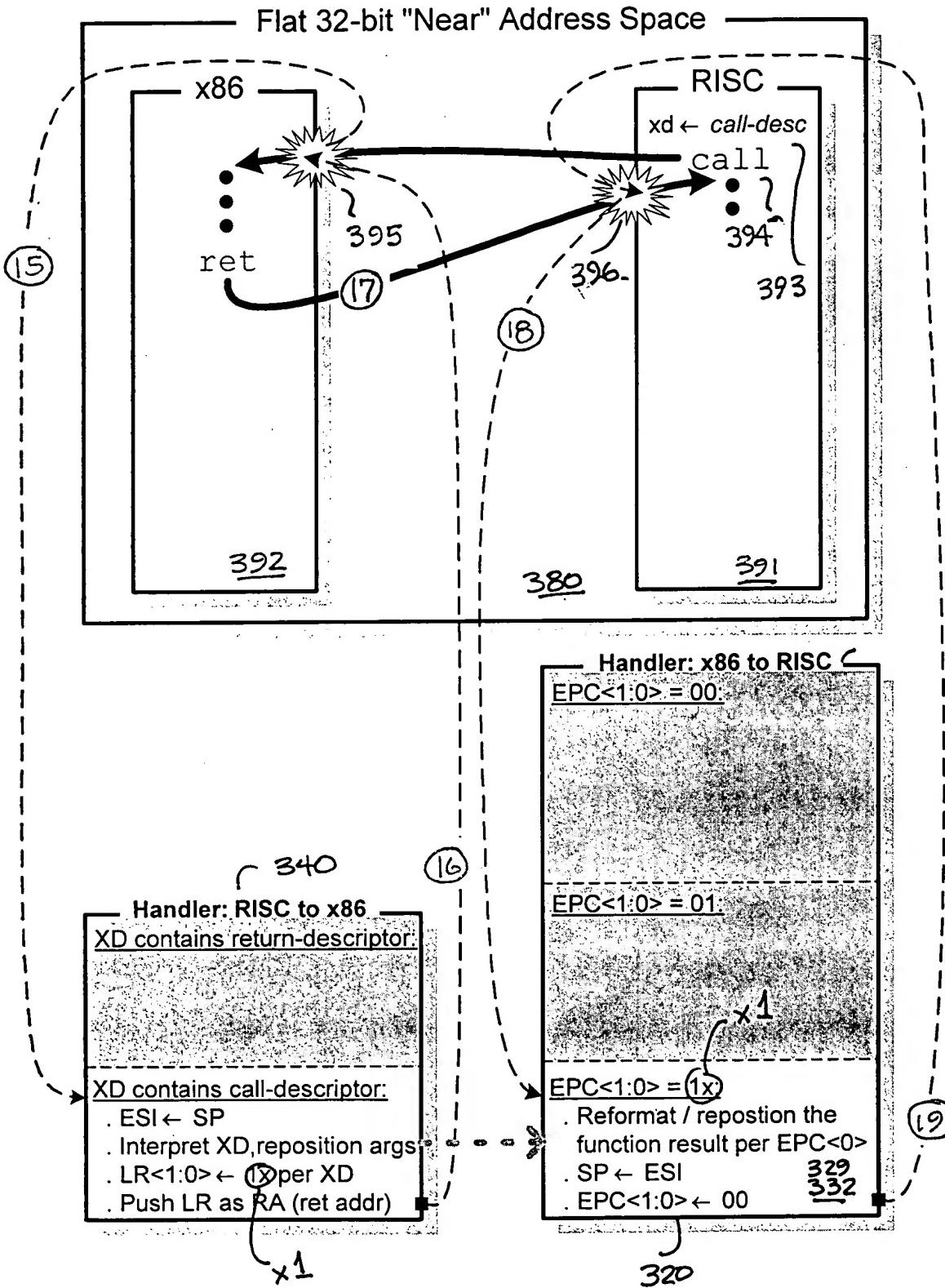
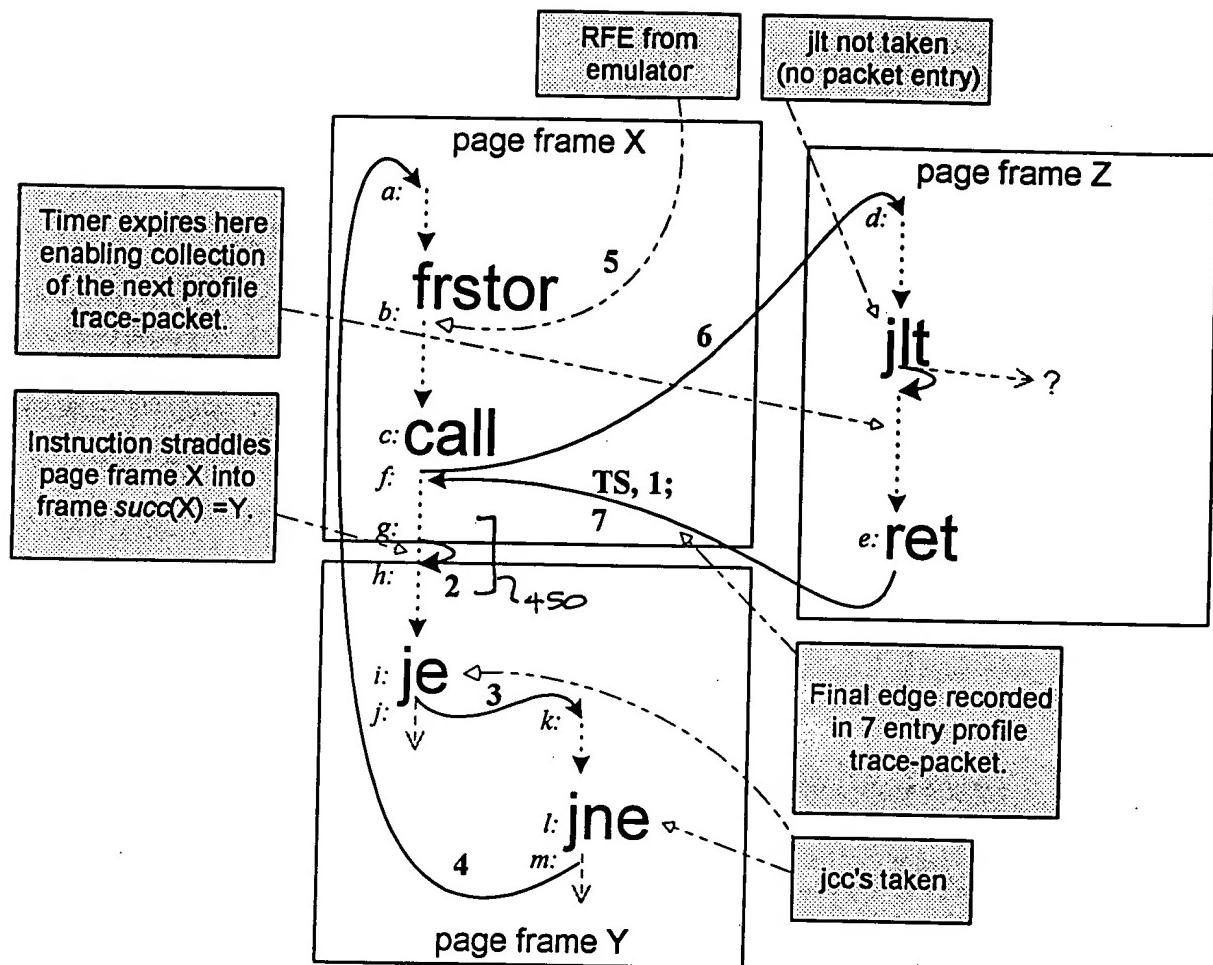


Fig. 30



7 entry trace packet

420 {

Entry	Event Code	Done Addr	Next Addr	
64 bit time stamp				
1	ret	x86 context	phys X:f	~ 450
2	new page	phys Y:g	phys Y:h	~ 440, 454
3	jcc forward	phys Y:i	phys Y:k	~ 440
4	jnz backward	phys Y:l	phys X:a	~ 440
5	seq; env change	x86 context	phys X:b	~ 430
6	ip-rel near call	phys X:c	phys Z:d	~ 440
7	near ret	phys Z:e	phys X:f	~ 440

Fig. 42

414
416
418
610
612

Source	Code	Event	Reuse event code	Profileable event	Initiate packet	Probeable event	Probe event bit - TLB probe attribute or Emulator probe
	<u>402</u>						
RFE (Context_at_Point entry)	0.0000	Default (x86 transparent) event, reuse all converter values	yes	no	no	no	
	0.0001	Simple x86 instruction completion (reuse event code)	yes	no	no	no	
	0.0010	Probe exception failed	yes	no	no	no	reuse event code
	0.0011	Probe exception failed, reload probe timer	yes	no	no	no	
	0.0100	flush event	no	no	no	no	-
	0.0101	Sequential; execution environment changed - force event	no	yes	no	no	-
	0.0110	Far RET	no	yes	yes	no	-
	0.0111	IRET	no	yes	no	no	-
	0.1000	Far CALL	no	yes	yes	yes	Far call
	0.1001	Far JMP	no	yes	yes	no	-
	0.1010	Special; emulator execution, supply extra instruction data ^a	no	yes	no	no	-
	0.1011	Abort profile collection	no	no	no	no	-
	0.1100	x86 synchronous/asynchronous interrupt w/probe (GRP 0)	no	yes	yes	yes	Emulator probe
	0.1101	x86 synchronous/asynchronous interrupt (GRP 0)	no	yes	yes	no	-
	0.1110	x86 synchronous/asynchronous interrupt w/probe (GRP 1)	no	yes	yes	yes	Emulator probe
	0.1111	x86 synchronous/asynchronous interrupt (GRP 1)	no	yes	yes	no	-
Converter (Near_Edge entry)	1.0000	IP-relative JNZ forward (opcode: 75, OF 85)	no	yes	yes	no	-
	1.0001	IP-relative JNZ backward (opcode: 75, OF 85)	no	yes	yes	yes	Jnz
	1.0010	IP-relative conditional jump forward - (Jcc, Jcxz, loop)	no	yes	yes	no	-
	1.0011	IP-relative conditional jump backward - (Jcc, Jcxz, loop)	no	yes	yes	yes	Cond jump
	1.0100	IP-relative, near JMP forward (opcode: E9, EB)	no	yes	yes	no	-
	1.0101	IP-relative, near JMP backward (opcode: E9, EB)	no	yes	yes	yes	Near jump
	1.0110	RET/ RET imm16 (opcode C3, C2 /w)	no	yes	yes	no	-
	1.0111	IP-relative, near CALL (opcode: E8)	no	yes	yes	yes	Near call
	1.1000	REPE/REPNE CMPS/SCAS (opcode: A6, A7, AE, AF)	no	yes	no	no	-
	1.1001	REP MOVS/STOS/LDOS (opcode: A4, A5, AA, AB, AC, AD)	no	yes	no	no	-
	1.1010	Indirect near JMP (opcode: FF /4)	no	yes	yes	no	-
	1.1011	Indirect near CALL (opcode: FF /2)	no	yes	yes	yes	Near call
	1.1100	load from I/O memory (TLB.asi != 0) { not used in TI }	no	yes	no	no	-
	1.1101	available for expansion	no	no	no	no	
	1.1110	Default converter event; sequential	<u>406</u>	no	no	no	-
	1.1111	New page (instruction ends on last byte of a page frame or straddles across a page frame boundary)	<u>408</u>	no	yes	no	-

a. Used by emulator for new x86 opcodes. Extra information supplied in *Taxi_Control.special_opcode* bits.

Fig. 4b

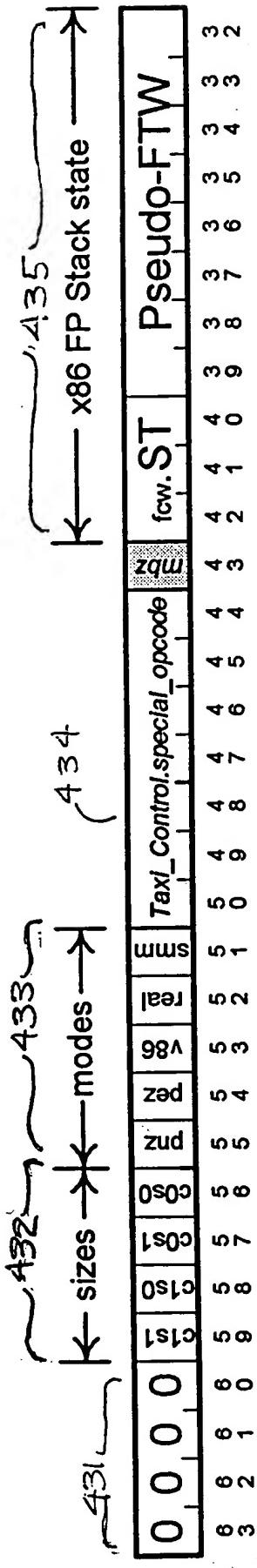


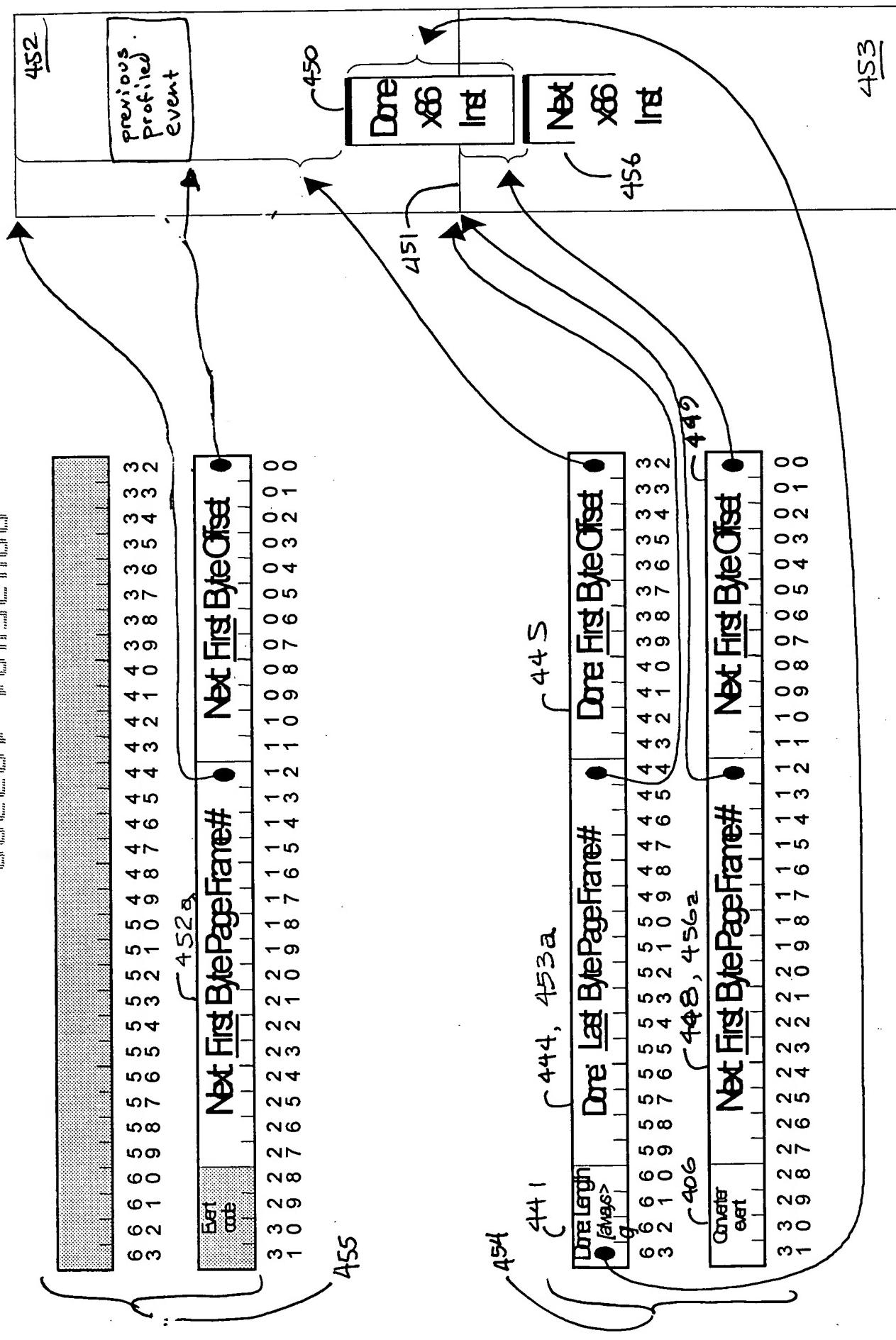
Fig. 4c. Context_At_Point profile trace-packet entry

44

440

Fig. 4c) Near_Edge profile trace-packet entry

Fig. 4e



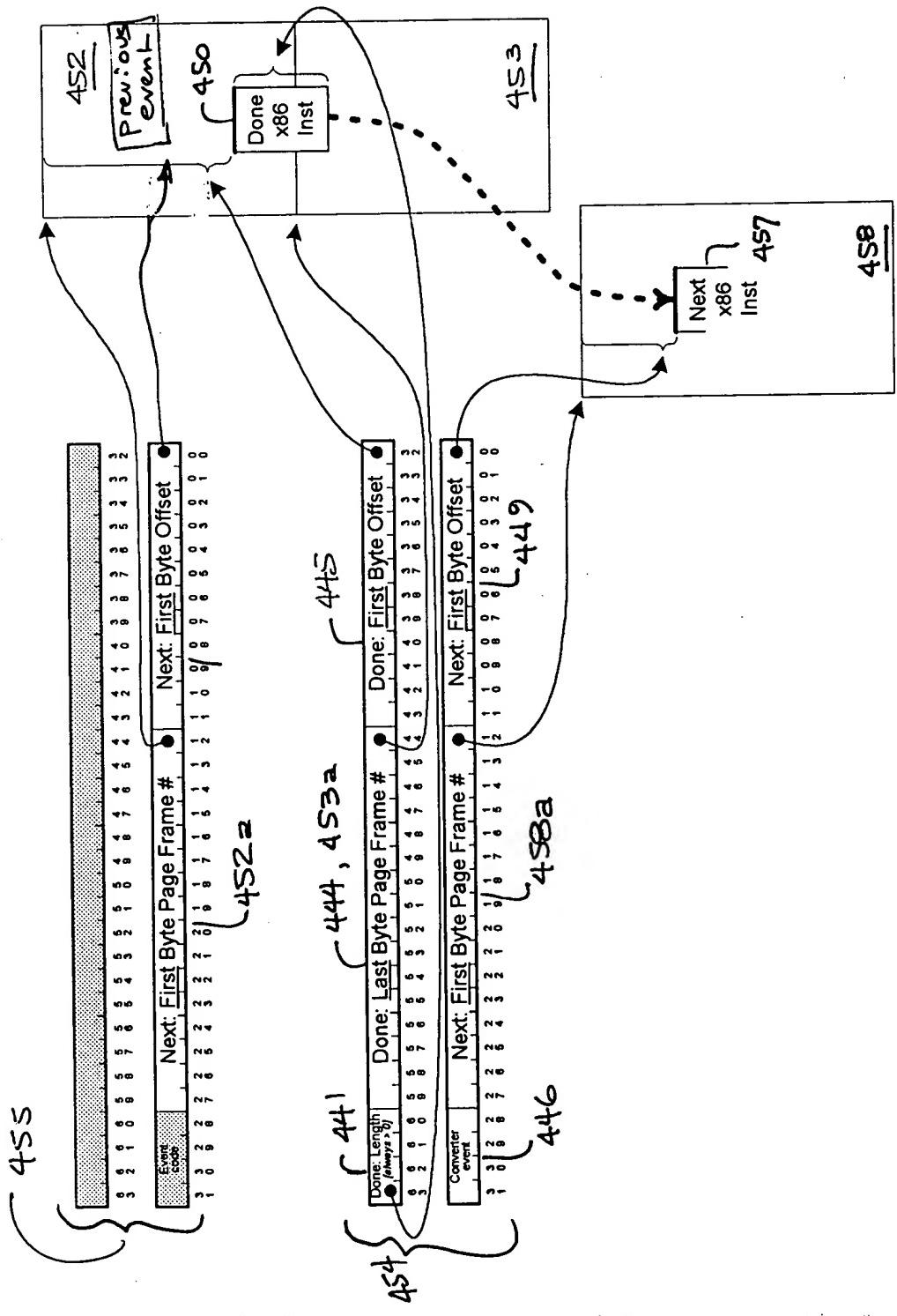


Fig. 4f

Global TAX! enables
sizes → modes →

470 → 472 →
466 → 2 → 462 → 2 → 464 → 2 → 468 → 2 → 476 → 2 → 470 → 472 → Global TAX! enables → sizes → modes →

probe	prot	ti	nr	unp	C151	S0	S03	S031	S032	PEd	98	Ems	Special_opcode	Packet_Reg_Last	Packet_Reg_First
6	6	6	5	5	5	5	5	5	5	5	5	4	4	4	4
3	2	1	0	9	8	7	6	5	4	3	2	1	0	9	8
1	0	9	8	7	6	5	4	3	2	1	0	9	8	7	6

Fig. 4g' Taxi_Control processor register 460

mbz	Decoded_Probe_Event	mbz	Probe_Mask	mbz	Event_Code_Latch	mbz	Packet_Reg
3	3	2	2	2	2	2	0
1	0	9	8	7	6	5	4

Fig. 4h Taxi_State processor register 480

mbz	Profile_Timer	mbz	Probe_Timer	mbz
3	3	2	2	2
1	0	9	8	7

Fig. 4i Taxi_Timers processor register 490

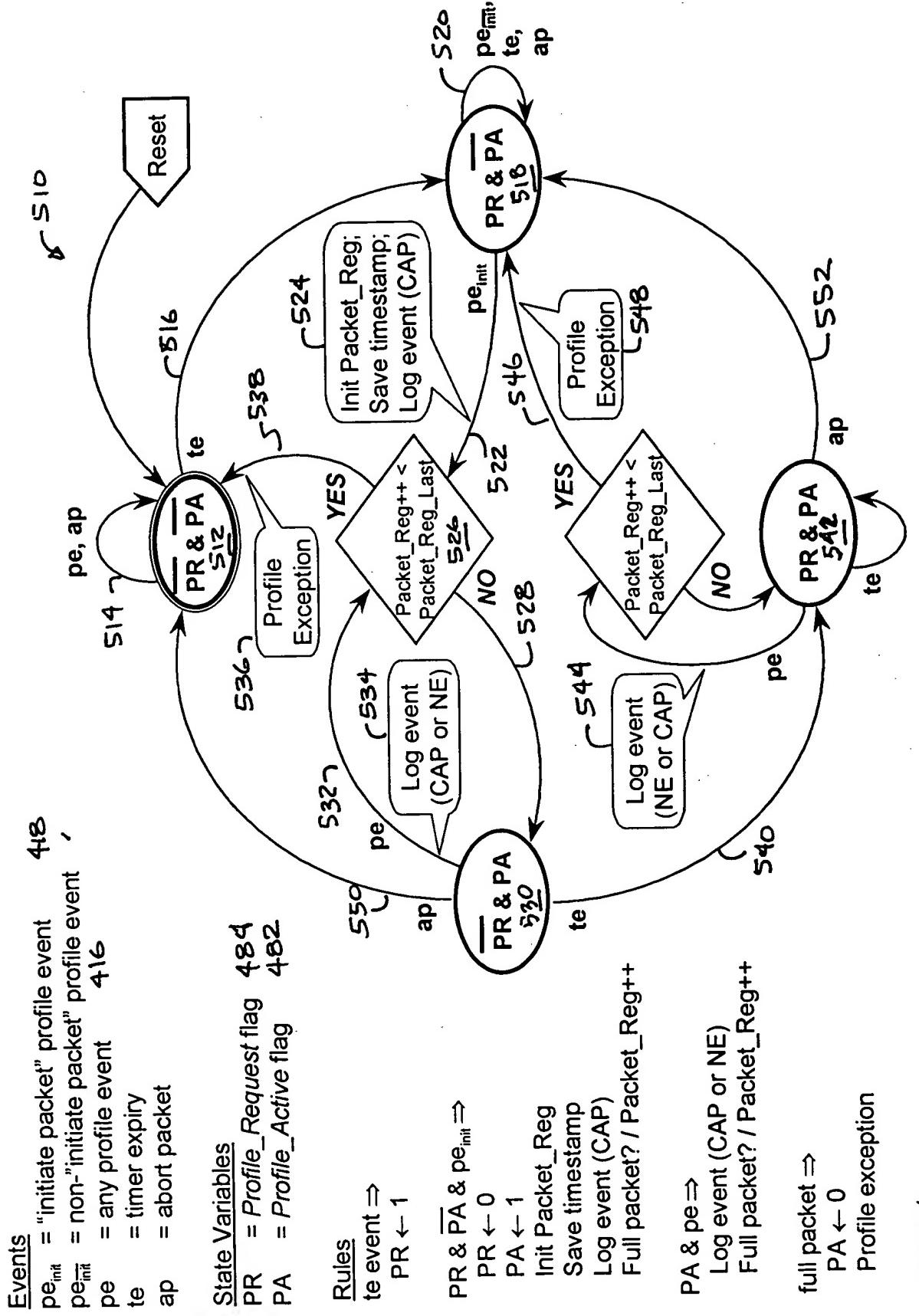


Fig. 5a

taxi profile entry generation

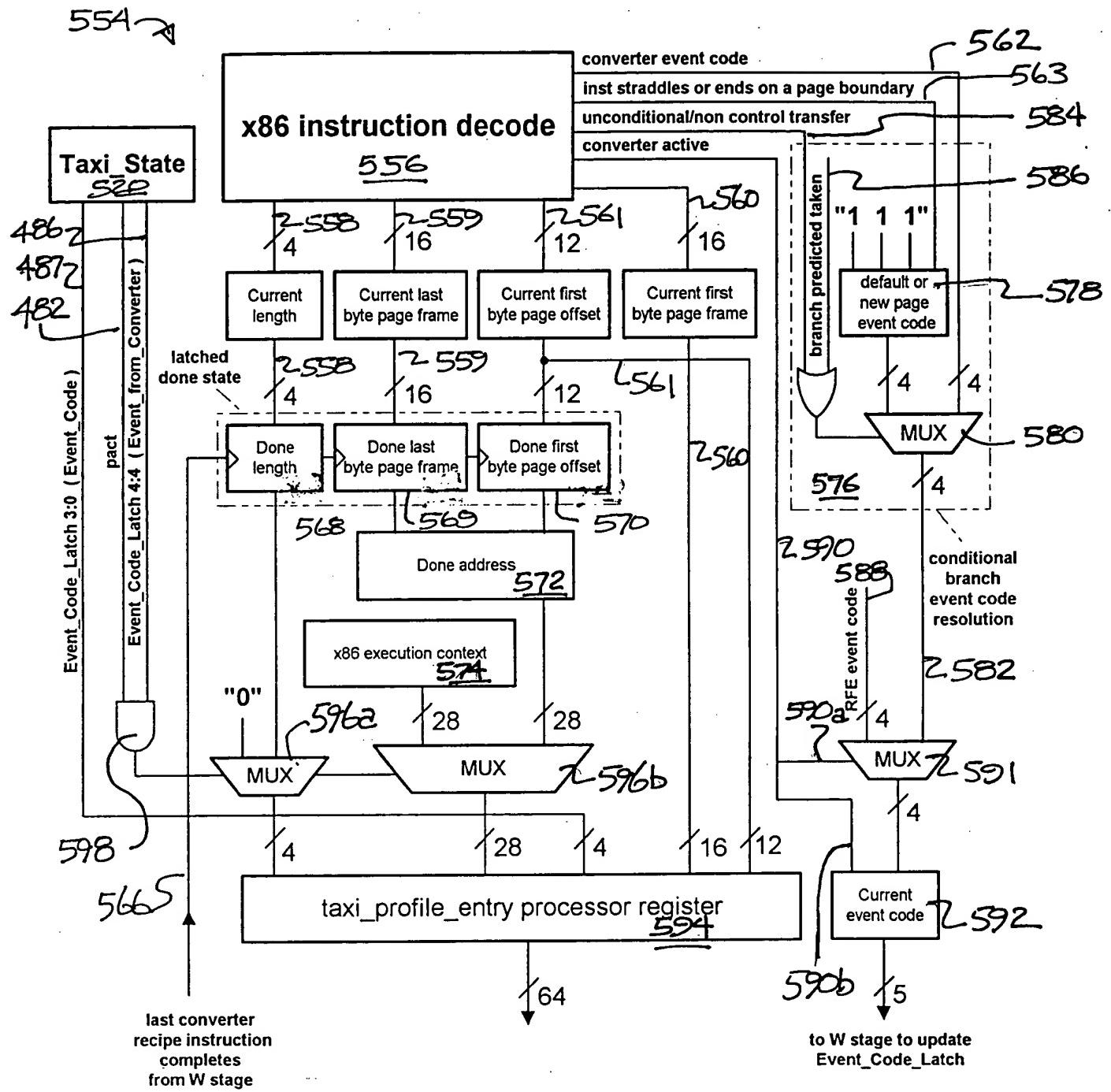


Fig. 5b

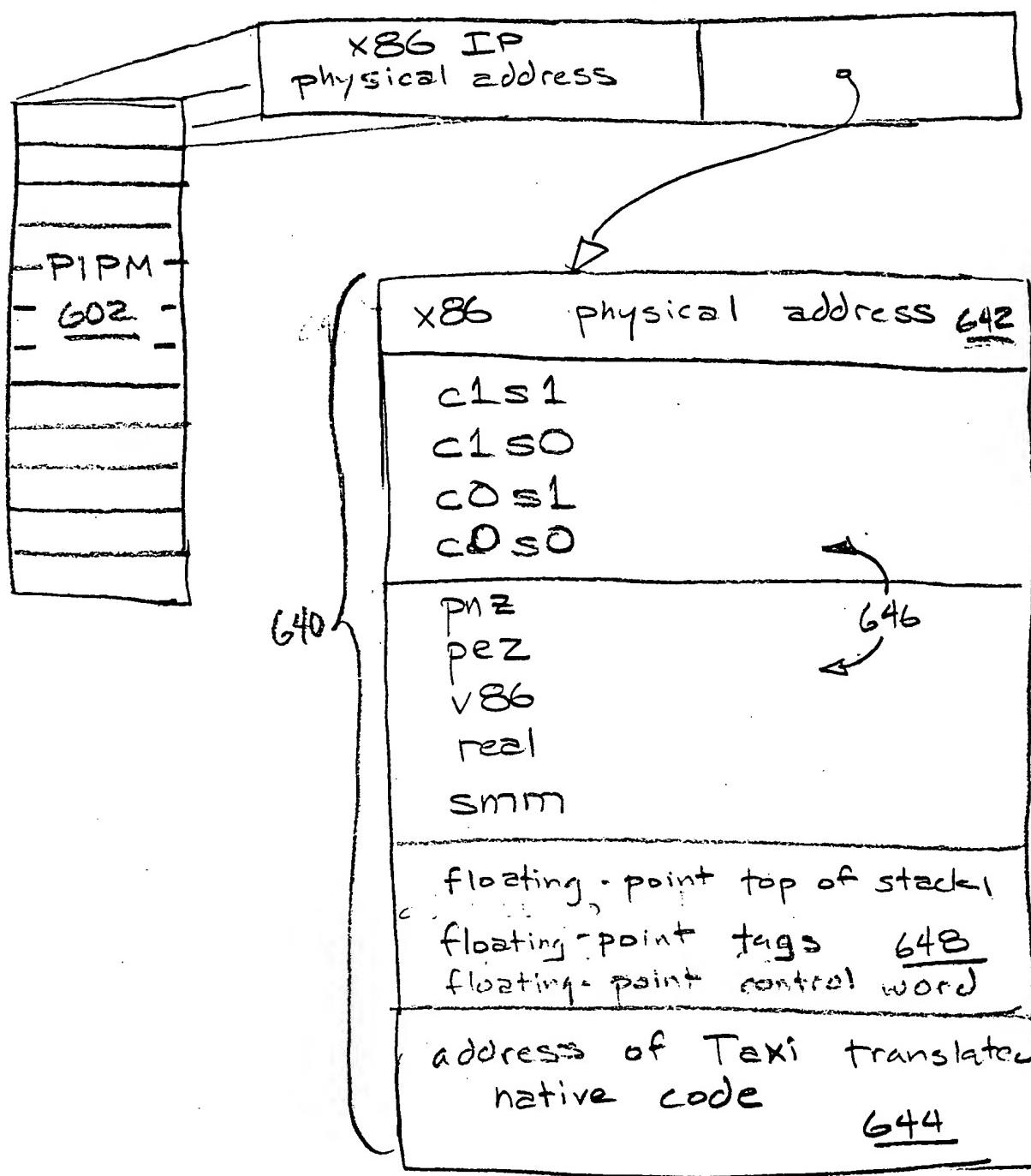
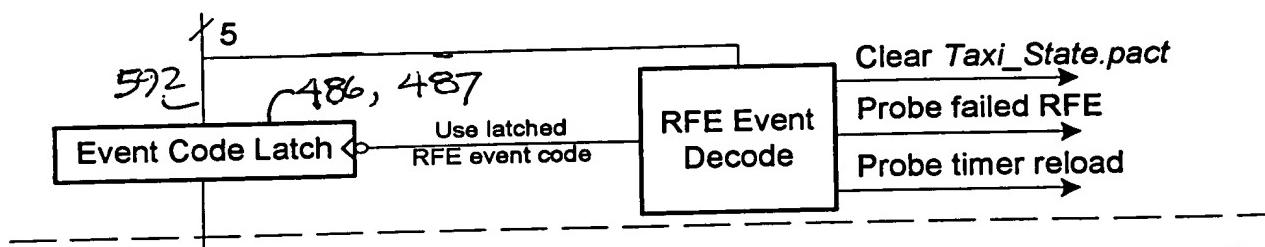


Fig. 6a

Event code from RFE restarting converter
or mapping of converter's x86 opcode

RFE or previous converter cycle



Next instruction cycle

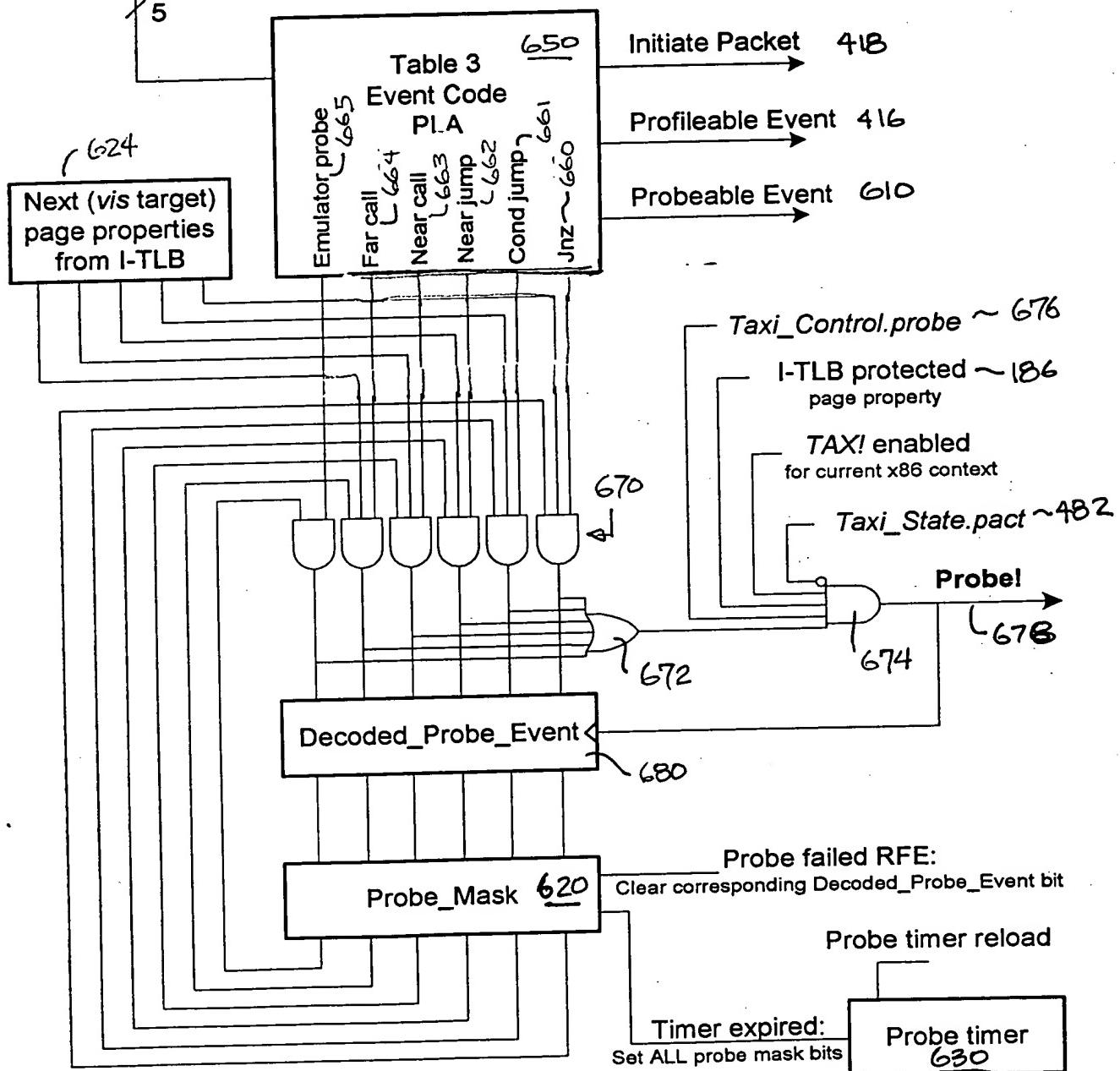


Fig. 6b

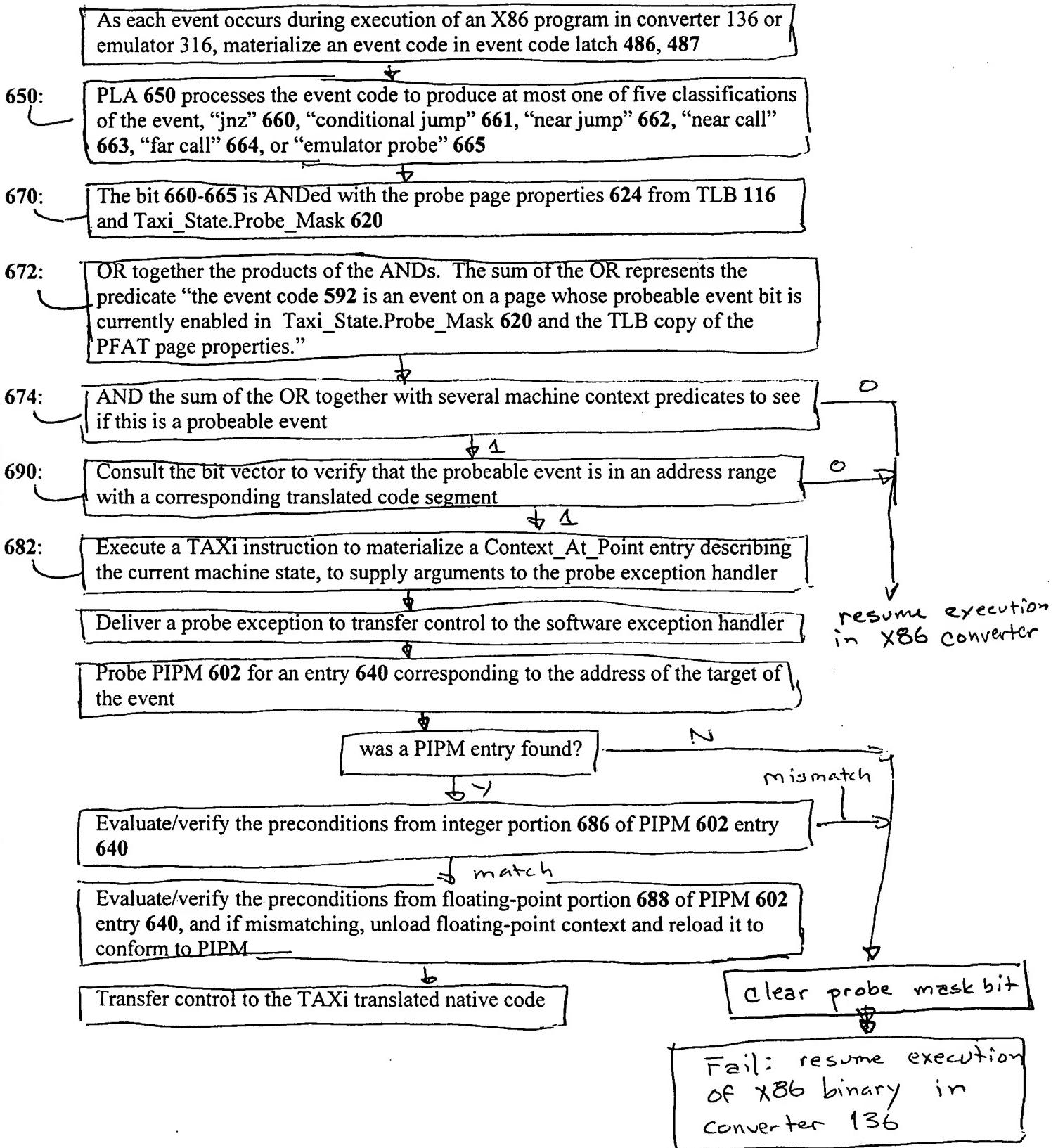


Fig. 6c

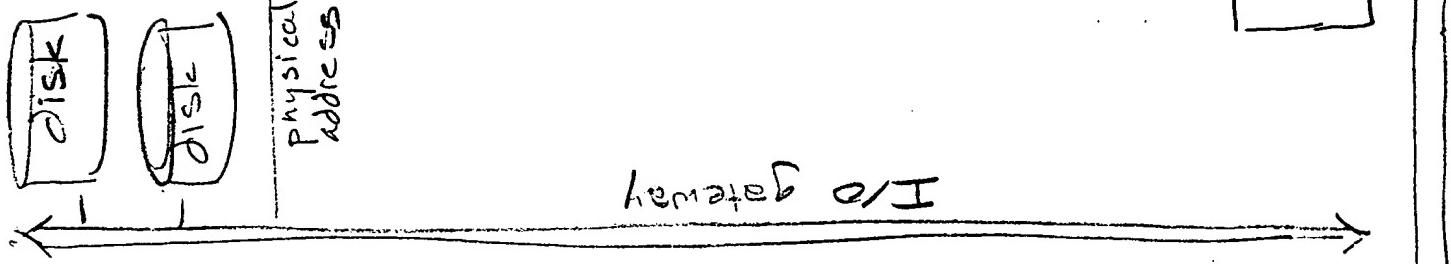


Fig. 72

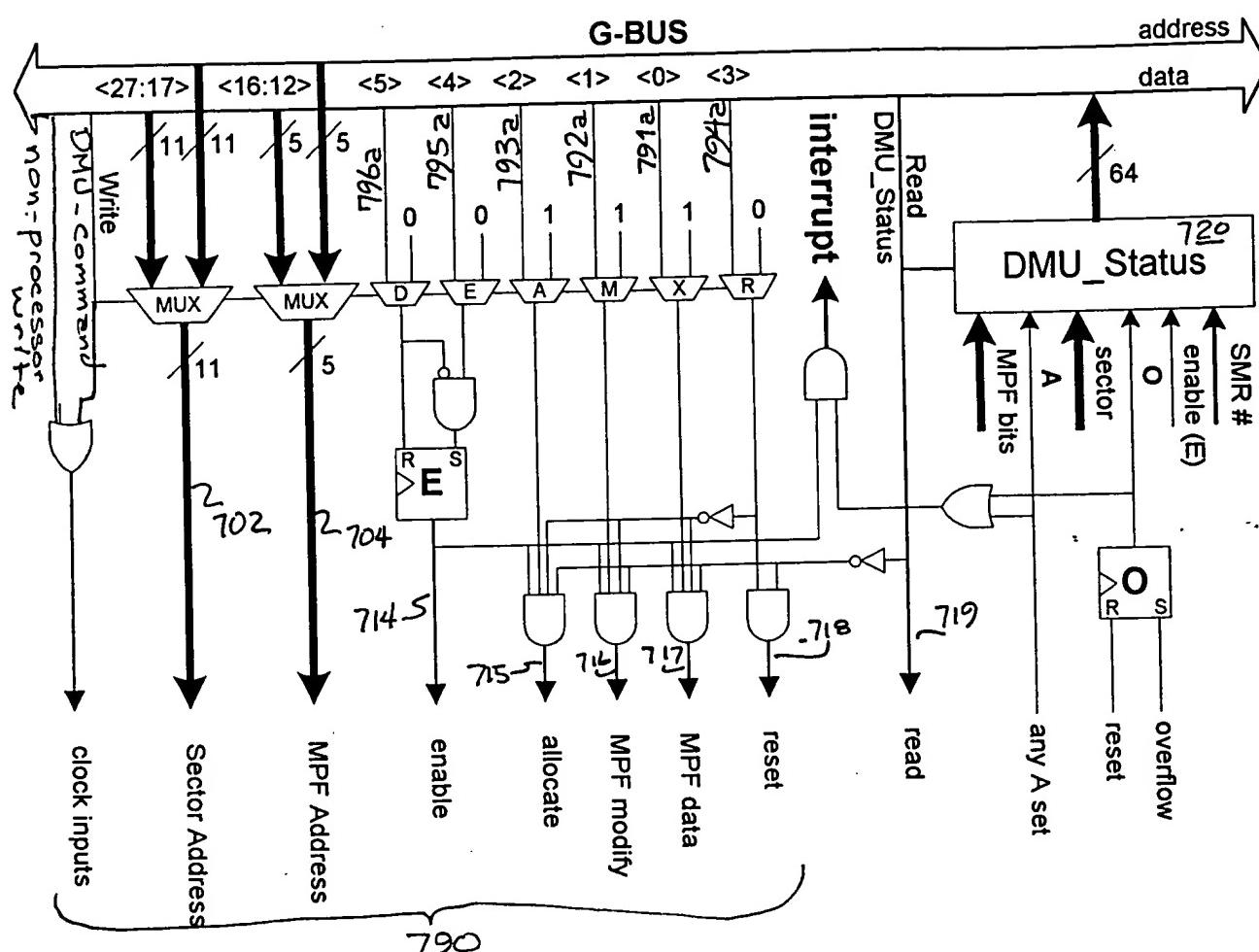


FIGURE 7b DMU interface

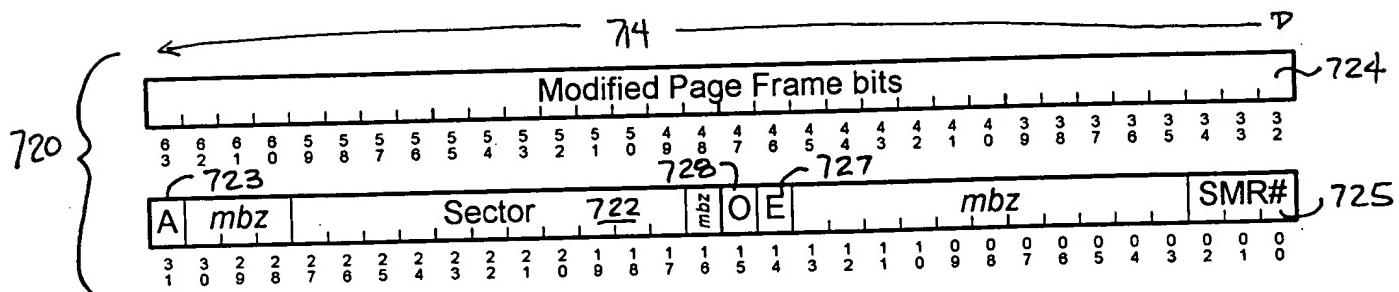


FIGURE 7c The 64-bit DMU Status register

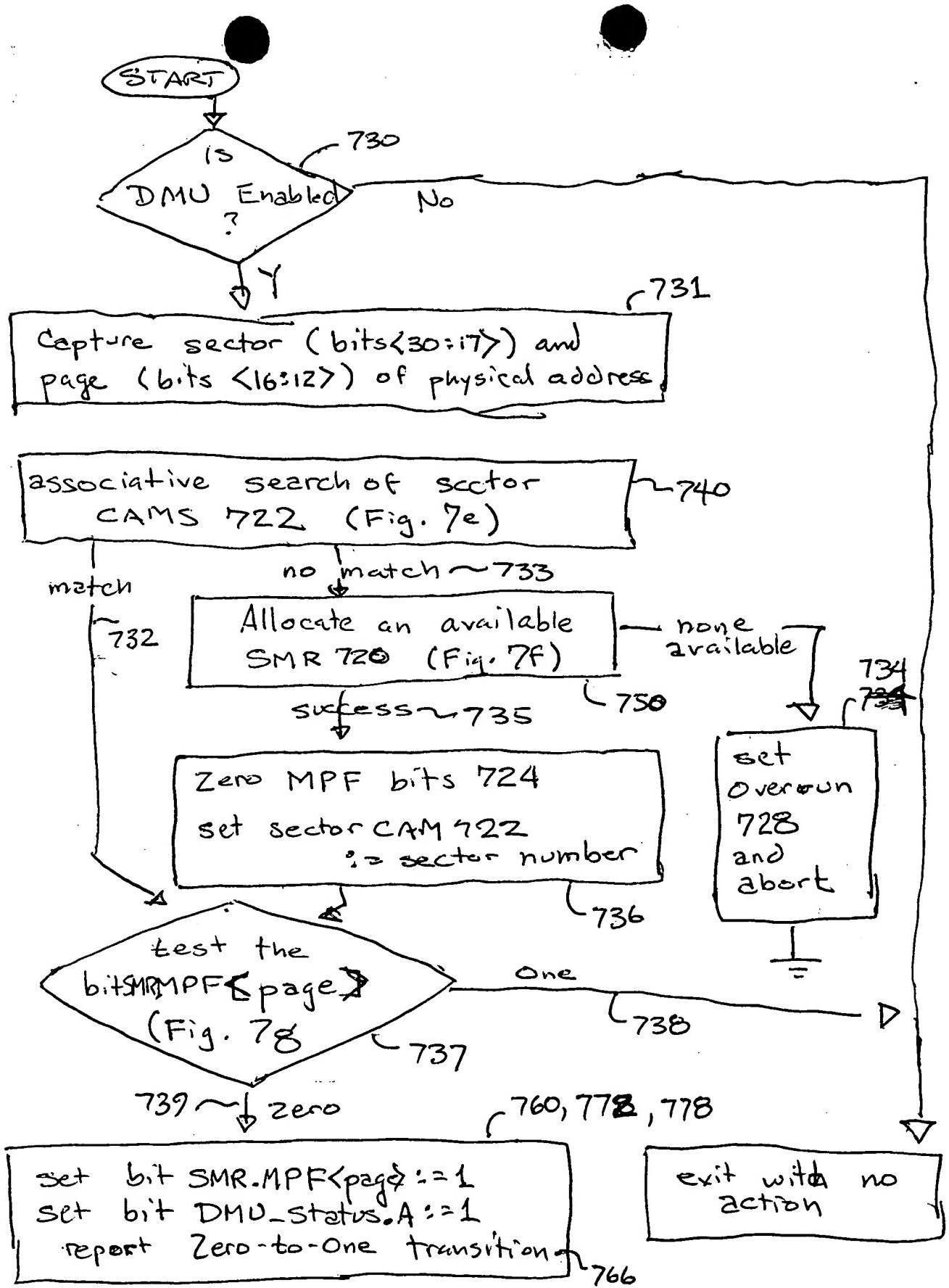


Fig. 7d

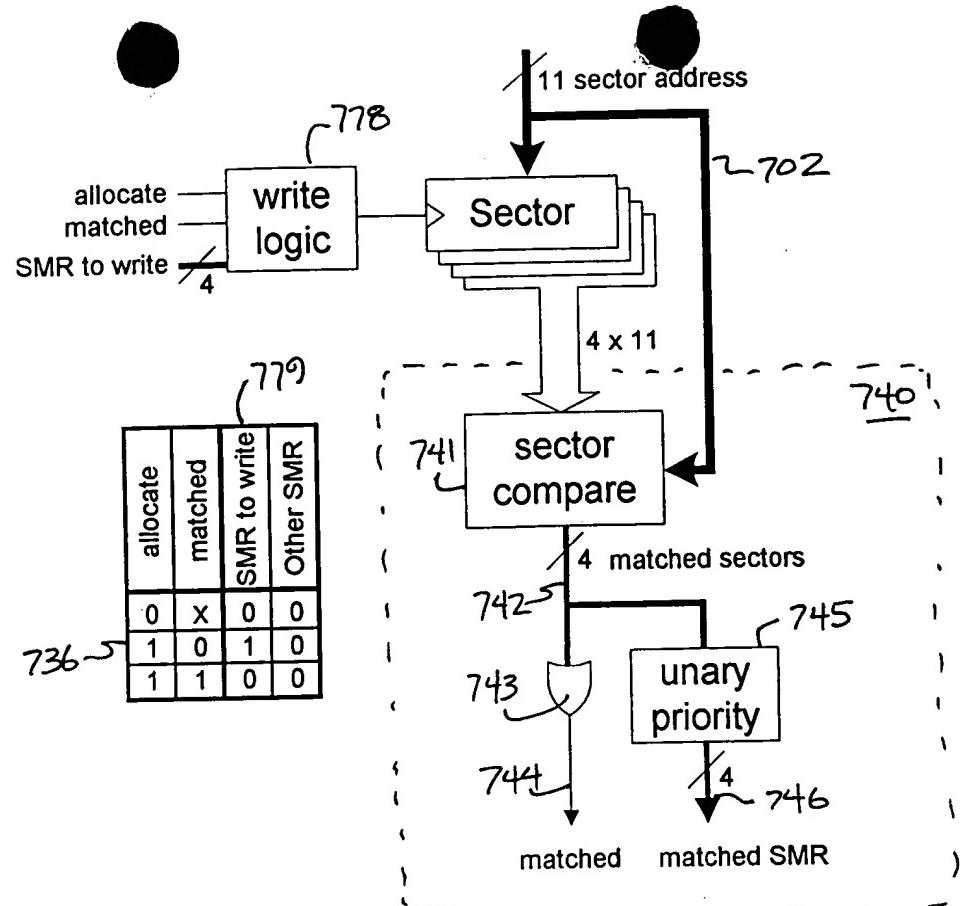


FIGURE 7e Sector match logic

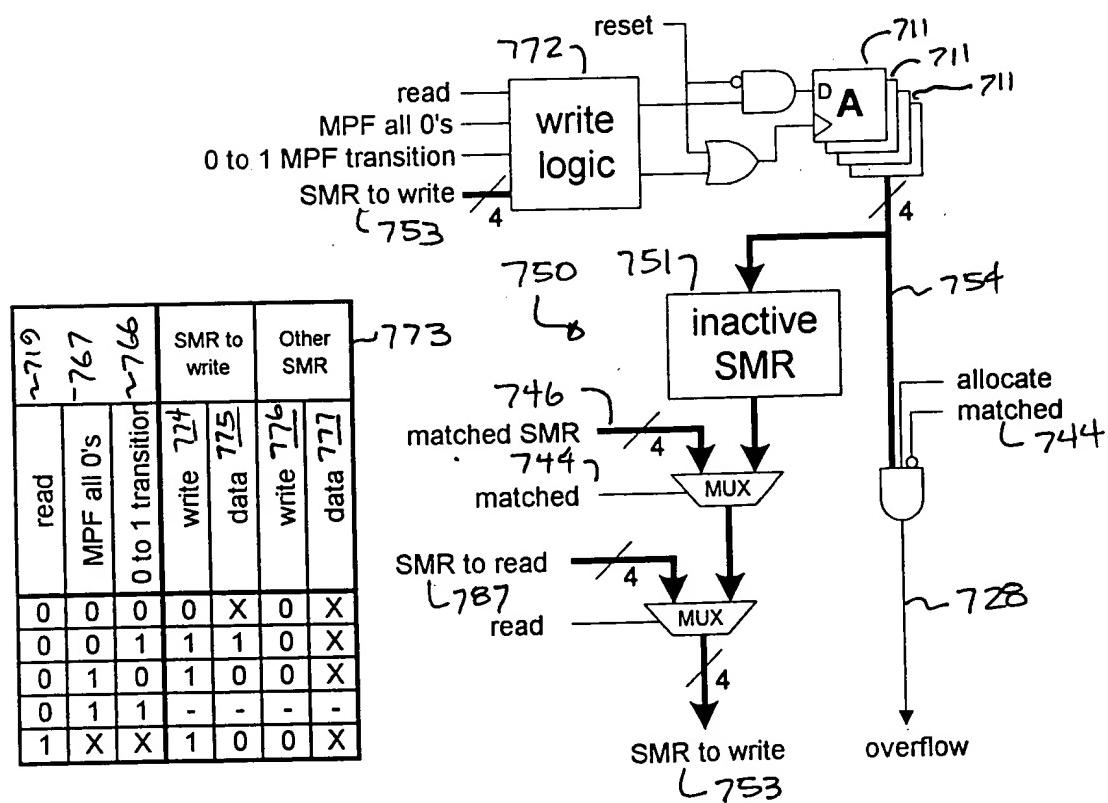


FIGURE 7f SMR allocation

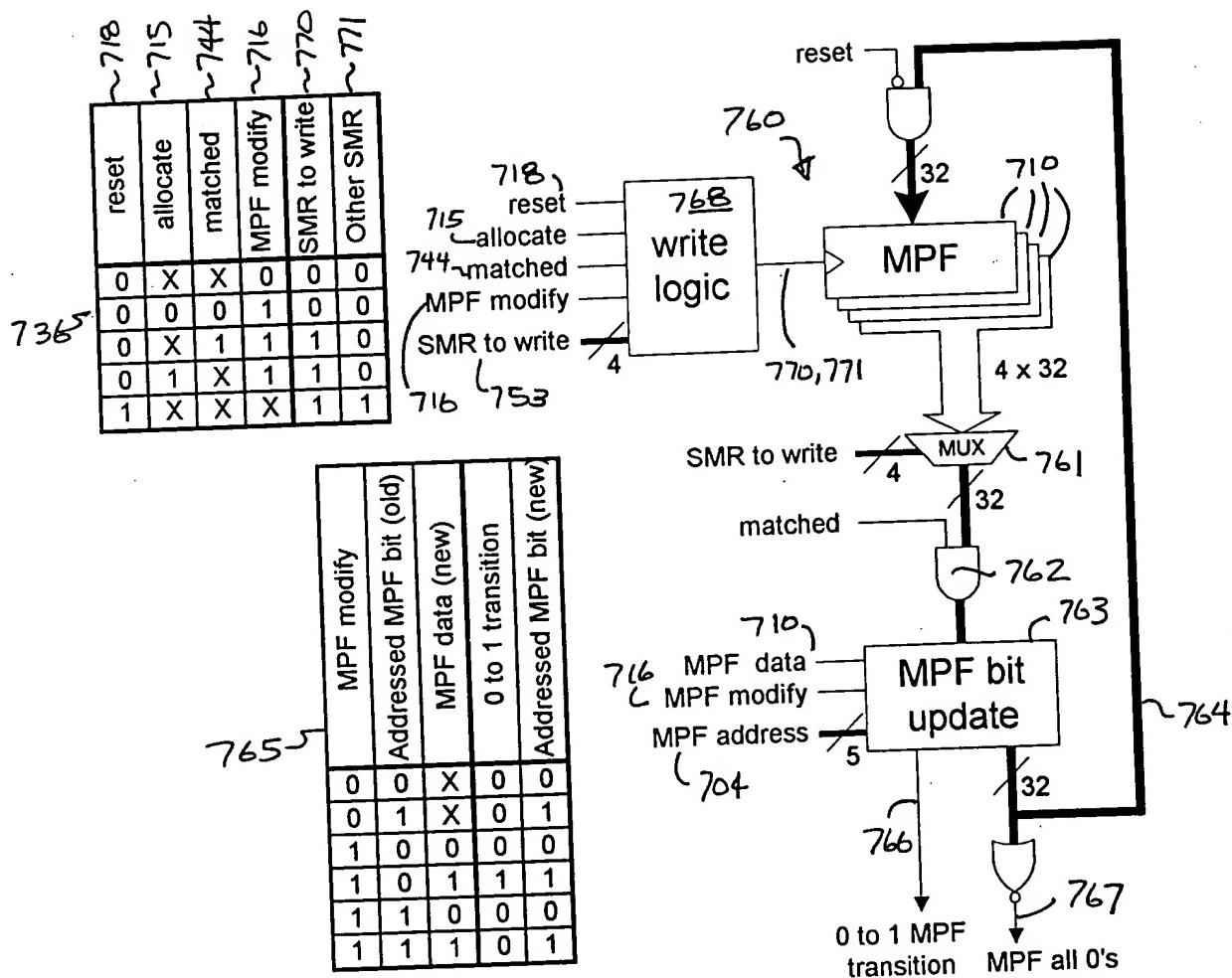


FIGURE 7g MPF update logic

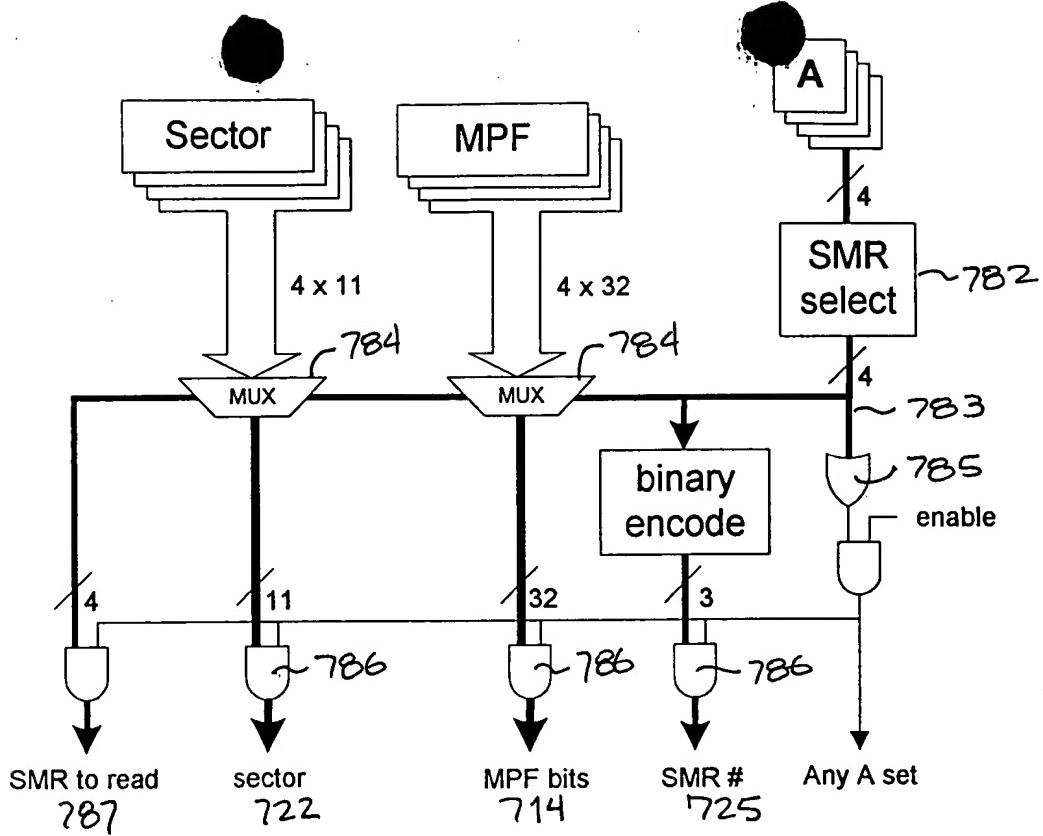


FIGURE 7h DMU_Status read

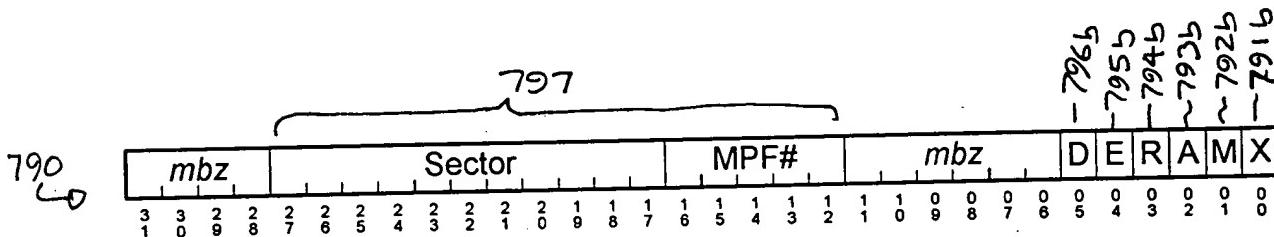
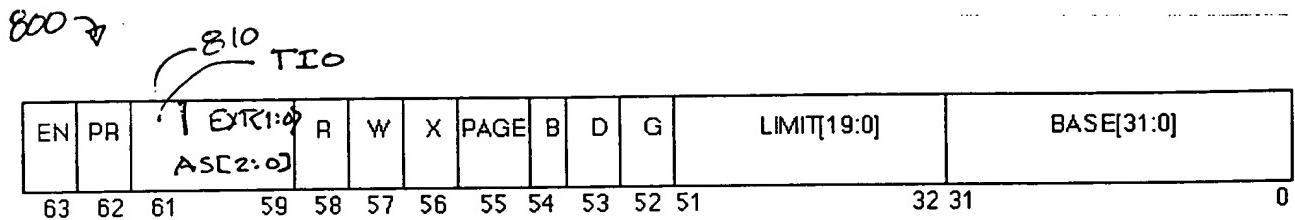


Fig. 7i

Command Bit	Bit Position	Meaning
D	5	Disable monitoring of DMA writes by clearing the DMU Enable flag
E	4	Enable monitoring of DMA writes by setting the DMU Enable flag
R	3	Reset all SMRs: clear all A and MPF bits and clear the DMU Overrun flag
A	2	Allocate an inactive SMR on a failed search
M	1	Allow MPF modifications
X	0	New MPF bit value to record on successful search (or allocation)

Fig. 7j : DMU Commands

M	X	Action
0	-	Inhibit modification of the MPF bit
1	0	Clear the corresponding MPF bit
1	1	Set the corresponding MPF bit

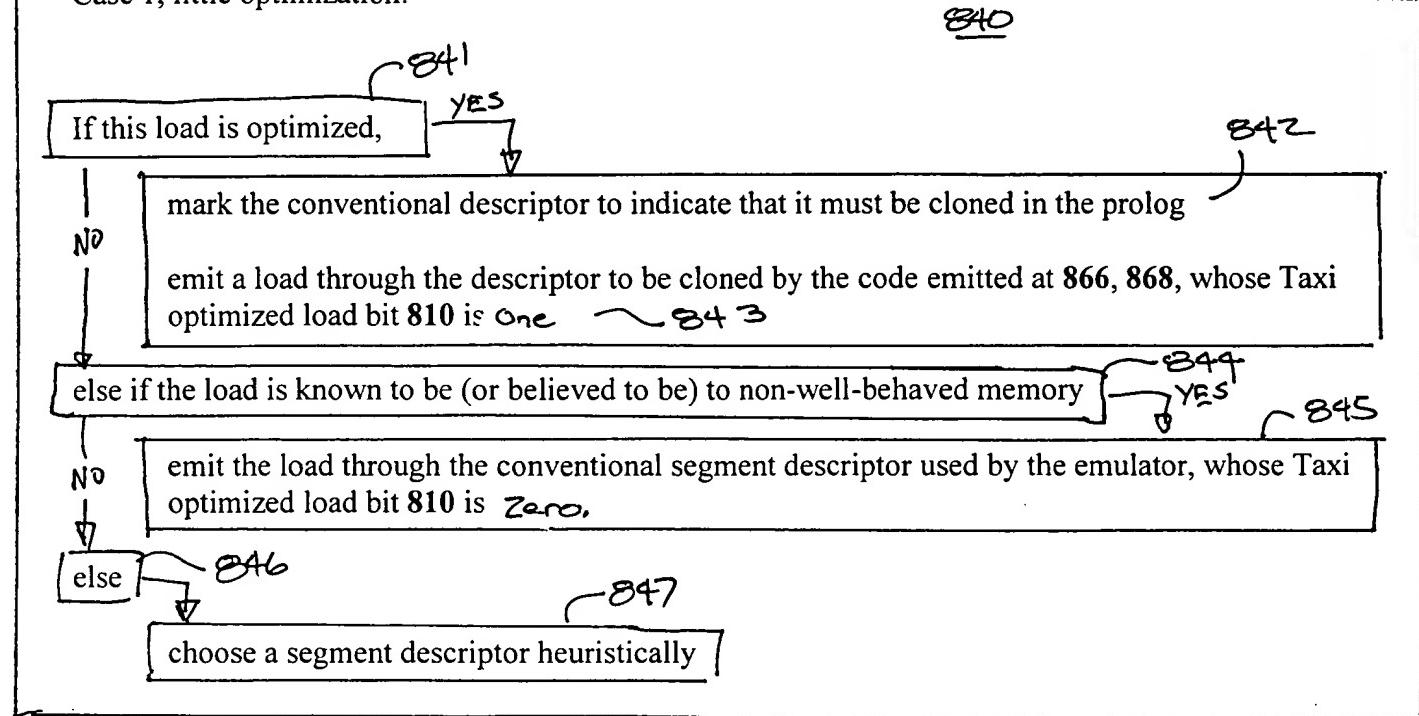


<u>Size</u>	<u>Bit(s)</u>	<u>Name</u>	<u>Function</u>
1	63	SEG.EN	enables segment limit/protection checking
1	62	SEG.PR	chooses which protection bits to use for page table protection - (0 means PSW.UK or 1 means MISC.UK)
3	61:59	SEG.AS	address space (only used when SEG.PAGE is 0)
		<u>SEG.TIO, SEG.EXT</u>	address space extension (only used when SEG.PAGE is 1)
3	58:56	SEG.RWX	read/write/execute '1' means enabled - all 000 means it's an invalid segment
1	55	SEG.PAGE	enables the paging system -- (translation and checking)
1	54	SEG.B	segment size (1 means 32-bit, 0 means 16-bit)
1	53	SEG.D	segment direction (0 means expand up)
1	52	SEG.G	size of limit (1 means it's in 4k pages)
20	51:32	SEG.LIMIT	segment limit
32	31:0	SEG.BASE	segment base

Fig. 8a

At code generation time:

Case 1, little optimization:



Case 2, aggressive optimization enabled:

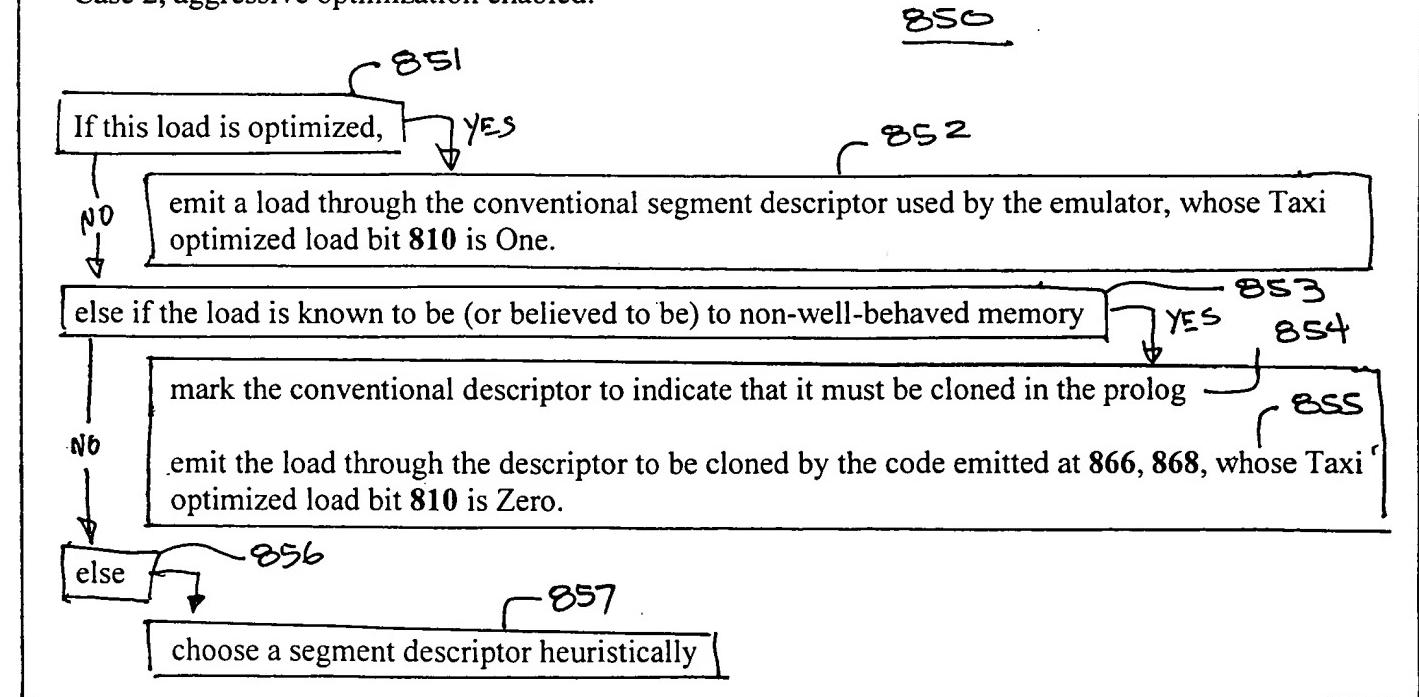


Fig. 8b

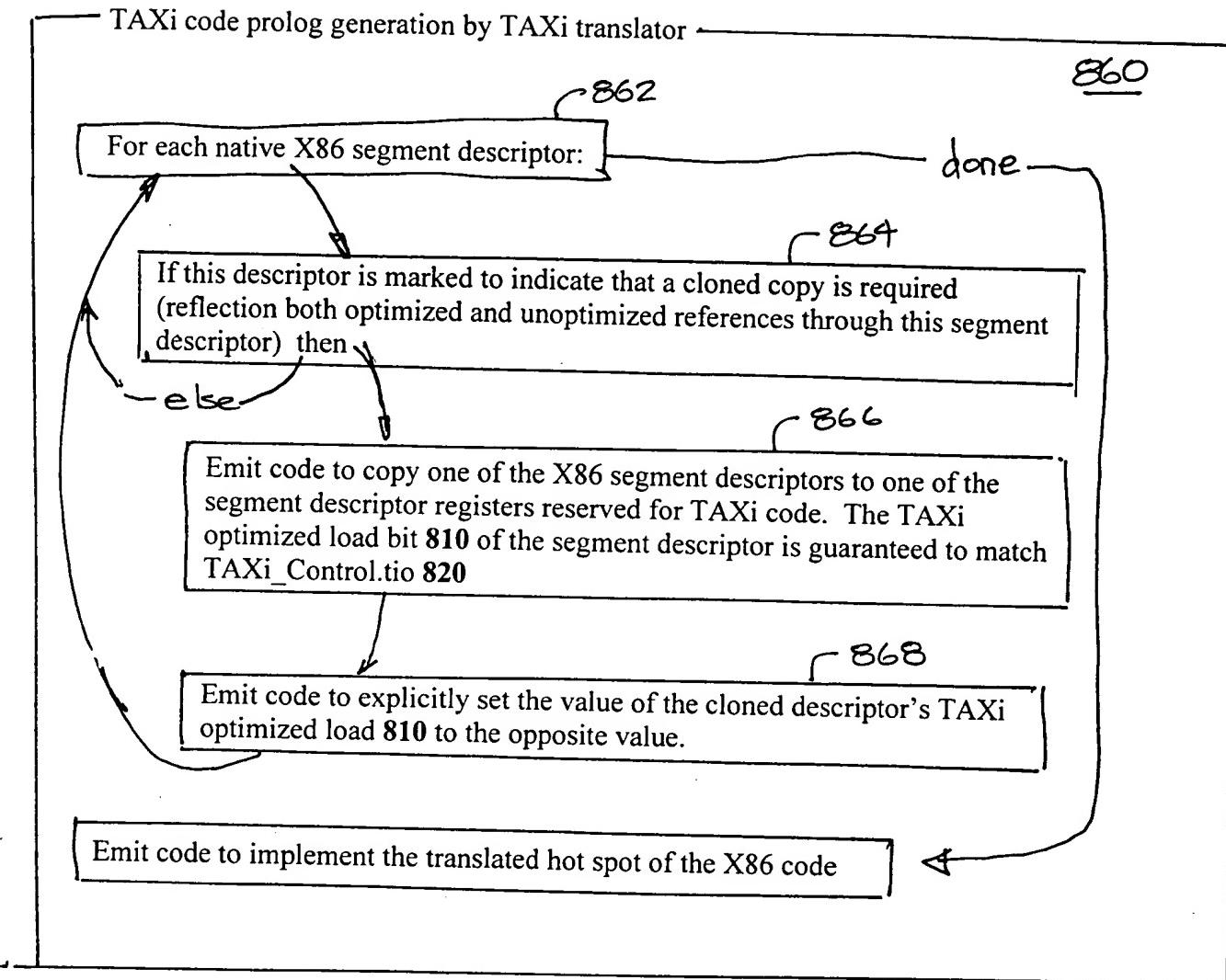


Fig. 8c